The Diet and Early Childhood Caries (DECC) Study: Validation of a Novel ECC Risk Assessment Tool and Investigation of Diet-Related ECC Risk Factors

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ABSTRACT

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Early Childhood Caries (ECC) is a highly prevalent disease afflicting approximately 28 percent of children in the U.S. under the age of 6 years (Bruce A Dye et al., 2007). ECC is a serious condition that can have profound health implications, including altered physical appearance, impaired ability to chew and speak, diminished quality of life, and increased risk for both oral and systemic health conditions (Colares & Feitosa, 2003; B. L. Edelstein, Vargas, & D, 2006; Norman Tinanoff & Reisine, 2009). Early identification of risk and prompt, targeted intervention is essential to overcoming the rising rates of ECC.

The Diet and Early Childhood Caries (DECC) study was designed to evaluate a novel risk assessment tool, MySmileBuddy (MSB), in a predominantly Spanish speaking, low income, urban population. MSB serves as an interactive platform for education and goal setting for ECC prevention and a comprehensive ECC risk assessment tool that incorporates questions evaluating diet, feeding practices, general attitudes and beliefs, fluoride use, and family history. A large component of the MSB tool is devoted to the assessment of dietary risk factors related to ECC via inclusion of a modified 24-hour dietary recall.

A primary aim of the DECC study was to establish concurrent criterion validity by evaluating if MSB *diet* and *comprehensive* scores were associated with physical evidence of risk (i.e., oral mutans levels, decalcifications, visible plaque, and ECC status). Additionally the DECC study aimed to examine associations between physical evidence of caries risk and overall

frequency of oral exposures, length of exposure time, and body mass index-for-age (BMI/age). Lastly, the DECC study was designed to assess the preliminary impact of the MSB intervention on recollection of stated goals and progress toward achievement of targeted ECC-related behavior changes one month post-intervention.

In 108 parent/child (caregiver/child) dyads, the *MSB diet risk scores* were found to be significantly associated with early stage indicators of caries risk, specifically oral mutans levels ($p < 0.05$), and borderline associated ($p < 0.1$) with visible plaque levels. The *MSB comprehensive risk score* was also found to be significantly associated with both oral mutans and visible plaque ($p < 0.05$). Children with high *MSB risk scores (diet* and *comprehensive)* were more likely to have higher levels of oral mutans, and more likely to have higher levels of visible plaque compared to children with lower scores. Physical indicators of caries risk were not associated with other factors included in the DECC study (i.e., frequency of oral exposures and intake of individual food/beverage categories, length of oral exposure time, and BMI/age weight status).

Preliminary data from the one-month follow-up suggests that the majority of parents/caregivers were able to recall their MSB goal and were beginning to initiate diet- and other dental-related changes at home. Overall, these findings suggest that the MSB tool may be a valid tool for predicting known physical precursors to caries and may be an effective avenue for behavior change. While these preliminary findings are encouraging, larger and longer-term studies will be necessary to determine the ultimate utility of MSB in predicting the ECC experience in children.

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CHAPTER 1

Introduction

This chapter provides a brief introduction and overview of the Diet and Early Childhood Caries (DECC) Study: Validation of a Novel ECC Risk Assessment Tool and Investigation of Diet-Related ECC Risk Factors. The following sections describe the background, rationale, purpose and significance of the DECC study.

1.1 – Introduction

Dental caries is an infectious and transmissible diet-dependent, fluoride-mediated, progressive, and highly prevalent disease of the mouth that results in dental cavities. In preschool age children, this disease is called Early Childhood Caries (ECC), but is commonly known as "baby bottle tooth decay" or maxillary anterior caries. As defined by the American Academy of Pediatric Dentistry (AAPD), ECC is the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries) or filled tooth surfaces (dmfs) in any primary tooth in a preschool-age child between birth and 71 months of age (American Academy of Pediatric Dentistry, 2011).

ECC is a highly prevalent and potentially devastating health condition in industrialized countries, affecting nearly 11 percent of two-year-olds, 21 percent of three-year-olds, 34 percent of four-year-olds, over 44 percent of five-year-olds, and disproportionately affecting children in underserved populations (i.e., low socioeconomic and immigrant populations) (Cruz, Chen, Salazar, & Le Geros, 2009; Francisco et al., 2007; Iida, et al., 2006; Moynihan & Petersen, 2004; Pieper et al., 2012; Touger-Decker & van Loveren, 2003). According to NHANES data, the prevalence of dental caries in children between the ages of 2 to 5 years is on the rise, increasing from 24 percent in 1988-1994 to 28 percent in 1999-2004 (Beltran-Aguilar et al., 2005; Bruce A Dye et al., 2007). Being five times more common than asthma, four times more common than childhood obesity, and twenty times more common than diabetes, ECC poses a significant health threat to young children (B. A. Dye et al., 2004; "Oral health in America: a report of the Surgeon General," 2000; C. Palmer, Burnett, & Dean, 2010).

As a serious health condition that affects children under the age of six years of age, ECC can have lasting health implications for years to come (Colares & Feitosa, 2003; B. L. Edelstein et al., 2006; Norman Tinanoff & Reisine, 2009). ECC has been associated with impaired growth and development of children, and elevated risk for future caries throughout life (American Academy of Pediatric Dentistry, 2011; "Oral health in America: a report of the Surgeon General," 2000; Norman Tinanoff & Reisine, 2009; Vania et al., 2011).

Poor oral health can give rise to profound health consequences for the individual throughout the lifespan. Oral health issues can lead to decreased appetite and diminished ability to eat, thus placing an individual at high risk for poor nutrition status which may result in unintentional weight loss, impaired wound healing and decreased resistance to infections, poor oral health, and poor general health (B. L. Edelstein et al., 2006; Mofidi, Zeldin, & Rozier, 2009; C. Palmer et al., 2010; Papas et al., 1989). Research has also identified significant relationships between oral infectious diseases and other chronic diseases, including cardiovascular disease (Genco, Grossi, Ho, Nishimura, & Murayama, 2005). Additionally, several studies have found that there may be an association between severe dental caries and both obesity and failure to thrive in childhood, likely as a result of shared etiological factors (Macek & Mitola, 2006; Reifsnider, Mobley, & Mendez, 2004; Tuomi, 1989; Vania, et al., 2011; Werner, Phillips, & Koroluk, 2010; Willershausen, Haas, Krummenauer, & Hohenfellner, 2004). Therefore, it is imperative that maintenance of proper oral health be encouraged in order to promote optimal lifelong systemic health.

As a result of these significant health consequences, ECC has been shown to exert a tremendous impact on quality of life and general functioning for children. Oral health problems resulting in dental pain affects children's regular activities of living, including eating, sleeping and playing (B. L. Edelstein et al., 2006). One study by Gift, et al. (1993) found that children between the ages of 5 and 7 years have been estimated to lose more than 7 million school hours in the United States annually due to dental problems, which are often the result of caries that began prior to school age (Gift, Reisine, & Larach, 1993). Another study of 4-year old children in Brazil (n = 77) found that 26 percent of children with severe caries had increased school absence, 31 percent were ashamed to smile, and 49 percent had difficulty eating (Colares & Feitosa, 2003). Quality of life, however, can be improved following restorative dental treatment under general anesthesia (P.E. Malden, et al., 2007). A study of parental perceptions of child oral health-related quality of life found significant improvements in quality of life following treatment for extensive dental caries, among a population of children who had been experiencing long-term negative consequences of caries, including pain, lack of sleep and diminished ability to eat (P.E. Malden, et al., 2007).

Due to its significant impact on young children's quality of life, incredibly high prevalence, and potential for increasing their risk of caries in the permanent dentition, ECC is viewed as one of the most serious and costly health conditions affecting young children (Norman Tinanoff & Reisine, 2009). A survey of medical expenditures conducted in 2006, found that 19.4 percent of children under the age of 5 years had a dental expenditure, resulting in a total expense of $729 million that year (Agency for Healthcare Research and Quality, 2009). ECC is most often treated via restorative care, utilizing dental fillings or surgical procedures, including extraction of teeth. Restorative care for ECC (including Severe-ECC) is the primary cause of childhood hospitalization for treatment under general anesthesia (Sheller, Williams, & Lombardi, 1997). Severe-ECC (S-ECC) refers to "atypical" or "progressive" or "acute" or "rampant" patterns of dental caries (American Academy of Pediatric Dentistry, 2011). In children younger than 3 years of age, any sign of smooth-surface caries is indicative of S-ECC; from ages 3 through 5 years, 1 or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth or a decayed, missing, or filled score of ≥ 4 (age 3), ≥ 5 (age 4), or ≥ 6 (age 5) surfaces also constitutes S-ECC (Drury et al., 1999). General anesthesia or deep sedation is often required for the treatment of S-ECC since many children are unable to cope with the extensive restorative care procedures needed (Norman Tinanoff & Reisine, 2009). In some of the most extreme cases, ECC has been associated with several deaths from sepsis as well as an unknown number of deaths related to anesthesia mishaps (Casamassimo, Thikkurissy, Edelstein,

& Maiorini, 2009; Otto, 2007). Dental restorations repair the structure of the tooth; they have only a limited life span, which may be why over 50 percent of children with severe ECC experience new caries lesions post-treatment (Alfano et al., 2001; Almeida, Roseman, Sheff, Huntington, & Hughes, 2000).

Unfortunately, restorative care does not treat the underlying disease process that is occurring in ECC. In order to treat the disease itself, factors associated with disease etiology must be addressed. ECC is recognized as a complex, multifactorial disease that results from a series of interactions between a susceptible host, cariogenic bacteria and cariogenic diet-related behaviors; thus dental caries is considered a dieto-bacterial disease (Tanzer, Livingston, & Thompson, 2001). Frequent (i.e., snacking, grazing) and prolonged (i.e., slow, long-lasting, highly-retentive) consumption of sugars in the diet (fermentable carbohydrates), and actions including putting children to bed with a bottle (containing sweetened beverages or milk/formula) and sipping from a bottle or training cup (containing sweetened beverages) throughout the day are diet-related behaviors that have been highly correlated with ECC (Berkowitz, 2003; Fisher-Owens et al., 2007; Kawashita, Kitamura, & Saito, 2011; Moynihan & Petersen, 2004; Reisine & Litt, 1993; Norman Tinanoff & Reisine, 2009). These diet-related behaviors alter the pH balance in the oral cavity and impact the concentration of cariogenic bacteria, thereby promoting destruction of the tooth surface via a process known as demineralization.

Because of the dynamic interplay between dietary, behavioral and bacterial factors in the development and progression of this disease, ECC cannot be effectively treated via restorative procedures alone. Successful mitigation of the health consequences associated with ECC must take into account the multifactorial nature of the disease. The prevalence of ECC may, therefore, be reduced through the development and application of effective risk assessment tools that incorporate key etiologic factors. Such tools would allow for the early identification of those at highest risk of ECC, and permit the subsequent application of targeted nutrition-related behavioral interventions designed to address the complex, multifactorial nature of this disease. The American Academy of Pediatric Dentistry (AAPD) recognizes the importance of early risk assessment in the prevention and management of ECC, however, they acknowledge that there are currently no assessment tools that can ensure accurate categorization of children by risk or predict future caries experience (Pediatric Oral Health Research and Policy Center, 2012).

Despite an overall decrease in the prevalence and severity of dental caries in adults over recent years, there has been no observed reduction in the rate of ECC in infants and preschool children (Beltran-Aguilar et al., 2005). Perhaps even more concerning is the fact that there has been research to suggest that ECC may actually be on the rise (Bruce A Dye et al., 2007). Such alarming statistics bolster the need and sense of urgency for effective tools, programs and interventions to mitigate this devastating health condition in children.

1.2 – Rationale

ECC is a diet-dependent disease. The importance of diet in the etiology and progression of ECC has been well established (Mobley, 2003; "Oral health in America: a report of the Surgeon General," 2000; Sanders, 2004; Touger-Decker & van Loveren, 2003). Consequently, diet-related behaviors have been identified as a logical target for interventions to reduce the prevalence and severity of ECC. Dietary recommendations to reduce ECC have been made by numerous leading health organizations, but they have been implemented with limited success (American Academy of Pediatric Dentistry, 1993-2012; American Academy of Pediatric Dentistry, 2011/2012; American Academy of Pediatric Dentistry, 2011; "Oral health in America: a report of the Surgeon General," 2000; Touger-Decker, 2007). There is a clear need for more effective implementation strategies and tools to combat the rising rates of ECC.

Development of effective risk assessment methods is essential to resolving the nation's "oral health crisis" ("Oral health in America: a report of the Surgeon General," 2000). Effective risk assessment should be the first step in implementing a comprehensive intervention protocol. Risk assessment allows for the identification of key factors related to ECC, helps identify those at risk, and clarifies their individual oral health intervention needs (Francisco et al., 2007). Because ECC is a complex, multifactorial disease, effective risk assessment models must be broadly defined beyond the biologic parameters of the classic caries model, to involve a combination of factors associated with disease development and progression (Pediatric Oral Health Research and Policy Center, 2012). ECC risk assessment models should incorporate evaluation of a multitude of ECC-related factors, including diet-related behaviors, fluoride exposure, susceptibility of the individual, socioeconomic status, cultural influences, and oral health behaviors (American Academy of Pediatric Dentistry, 2011/2012).

Existing risk assessment tools for ECC, though not consistently utilized in practice, incorporate very limited assessment of dietary intake, assessing only frequency of between-meal snacks/beverages and bottle exposures of sugary beverages. A comprehensive ECC risk assessment tool should include evaluation of several key areas in the diet assessment portion of the interview, including frequency of dietary exposures (meals and snacks), the structure of meals and snacks, and the manner and frequency of sugared beverage intake, including: 100 percent juice, juice drinks, soft drinks, sports drinks, energy drinks, and sugared coffee and tea (Marshall, 2009). These ECC risk assessment tools should also consider how foods and beverages impact caries risk when they are consumed in combination.

In an effort to develop a more comprehensive and effective tool for assessing ECC risk, a multidisciplinary team of health researchers from the fields of behavioral nutrition, community pediatrics, public health, pediatric dentistry, social work, health education, informatics, information technology, diabetes education, peer counseling and policy research was formed. This diverse team of researchers collaborated on an RC1MD00425701 study funded under the ARRA Challenge Grant Program on a proposal entitled Bio-Behavioral Chronic Disease Management by Families of Young Minority Children. A primary aim of this study was to create a computer-based application for a portable electronic device (iPad) that could be administered by a community health worker. The iPad application, entitled MySmileBuddy (MSB) was developed as a risk assessment tool for the identification of children under the age of 6 years who may be at risk for ECC, as well as an interactive platform for intervention.

MSB was developed on a foundation of key constructs from several behavioral theories (health belief model, theory of planned behavior, theory of reasoned action, trans-theoretical/stages of change model, and social theories of behavior change), and was designed to incorporate the evaluation of targeted behavioral determinants (B. Edelstein, 2009-2011). The various assessment modules built into MSB were created to assess psychosocial determinants (e.g., health belief, locus of control, self-efficacy, and self regulation), knowledge determinants (e.g., understanding caries pathogenesis, caries control, the roles of diet and fluoride in caries management/prevention), logistic determinants (e.g., family organization and child care arrangements that may serve as barriers or facilitators of change), social and cultural determinants (e.g., social norms and expectations), and environmental determinants of the built environment (e.g., availability of healthy foods/beverages and oral dentifrices) that likely contribute to ECC risk (B. Edelstein, 2009-2011). The inclusion of these key theoretical constructs permits the individual administering MSB to follow a systematic approach to evaluating family capacity for behavior change, and to design a tailored approach to providing appropriate education and individualized behavior change guidance.

As a comprehensive ECC risk assessment tool, MSB incorporates five risk assessment modules containing a sequence of targeted questions evaluating diet, feeding practices, thoughts and feelings, fluoride, and family history. Additionally, MSB incorporates various interactive education features including text, images, and videos. Upon completion of these various modules, MSB prompts the individual to identify targeted goals for eliciting behavior change (also allowing for modification to identified goals over time) to increase the likelihood of engagement in successful behavior change. A large component of the MSB tool is devoted to the assessment of dietary risk factors related to ECC. The dietary risk assessment module was created to thoroughly assess diet-related behaviors associated with ECC via inclusion of a modified 24-hour dietary recall. The modified dietary recall was designed to be administered in a similar manner to a traditional 24-hour dietary recall, where participants are prompted to recall and state all foods and beverages consumed over the preceding 24 hours. However, in contrast to a traditional dietary recall, the MSB dietary recall module is structured to collect only specific dietary information relevant to ECC risk, and incorporates a collection of commonly consumed food and beverage photographs that participants are asked to select and identify as being consumed along a 24-hour timeline.

1.3 – Purpose

The Diet and Early Childhood Caries (DECC) study was designed to validate the MSB risk assessment tool, specifically the dietary assessment component, in an urban, Spanish-speaking, low-income population. A primary aim of the DECC study was to establish criterion validity of the MSB tool by concurrently evaluating if diet and dietary intake patterns, as assessed by the MSB risk assessment tool, are associated with ECC, as measured by physical evidence of ECC risk (oral mutans, decalcifications, visible plaque, and ECC status). Additionally the DECC study aimed to identify several diet-related risk factors for ECC, including associations between ECC and consumption of specific foods, dietary intake patterns, and body mass index-for-age (BMI/age) among participants. Furthermore, the DECC study was also designed to evaluate the data collected to assess the impact of the MSB intervention on recollection and achievement of targeted ECC-related behavior change goals one month post-intervention.

1.4 – Research Questions and Hypotheses

1. Using the MSB risk assessment tool, is there an association between reported food and beverage intake and physical evidence of ECC risk (specifically oral mutans levels, visible plaque, decalcifications and ECC status)?

   a. As measured by frequency (number of exposures) of food and beverage intake occurrences and physical evidence of ECC risk.

   Hypothesis: Children with a higher reported frequency of food and beverage intake will have greater physical evidence of caries risk compared to children with a lower reported frequency of food and beverage intake.

   b. As measured by type of food and beverage categories and physical evidence of ECC risk.

   Hypothesis: Children consuming higher frequencies of food and beverages in the low cariogenic risk categories (e.g., nuts, milk, cheese, meats, starchy vegetables, unsweetened grain products, fruit) will have less physical evidence of caries risk compared to children consuming lower frequencies of these foods and beverages. Similarly, children consuming higher frequencies of food and beverages in the high cariogenic risk categories (e.g., flavored milk, candies, salty snack foods, sweetened cereals, sugared beverages) will have greater physical evidence of caries risk compared to children consuming lower frequencies of these foods and beverages.

2. Using the MSB risk assessment tool, is there an association between the calculated risk scores (diet and comprehensive) with physical evidence of caries risk?

Hypothesis: Children with higher calculated MSB risk scores will have greater physical evidence of caries risk compared to children with a lower calculated diet risk score.

3. Is there an association between reported length of eating or drinking occurrence and physical evidence of caries risk?

a. As measured by a single question (*Is your child a quick eater/drinker or a slow eater/drinker?).*

Hypothesis: Children that are reported to be slow eaters/drinkers will have greater physical evidence of caries risk compared to children reported to be quick eaters/drinkers.

b. As measured by time captured before and after meals/snacks based on a one-day food record in a subset of the sample.

Hypothesis: Children with lower total average minutes spent eating or drinking throughout the day will have less physical evidence of caries risk compared to those with higher total average minutes.

4. Is there an association between body mass index-for-age (BMI/age) percentiles and physical evidence of caries risk?

   Hypothesis: Children with BMI/age percentiles at the extremes (below the 5^{th} or above the 95^{th} percentile) with have greater physical evidence of caries risk compared to those with BMI/age percentiles within a healthy range.

5. Is there an effect of the MSB intervention, as measured by self-reported behavior change, at one month post-intervention?

   Hypothesis: Parents who recall MSB behavior change goals at one month post-intervention will report engaging in targeted ECC-related behavior changes.

1.5 – Significance

Validation of the MSB risk assessment tool offers the potential for widespread application of this novel assessment tool in a variety of settings and programs that address the health needs of young children. Early identification of risk and prompt, targeted intervention is essential to overcoming the rising rates of ECC. Despite the preponderance of data recognizing the integral role of diet on ECC development and progression, previously developed ECC risk assessment tools have failed to comprehensively evaluate the contribution of diet-related behaviors on ECC risk in combination with other known ECC risk factors. The DECC study was conducted as an evaluation of the MSB ECC risk assessment tool, specifically the modified 24-

hour dietary recall module. Findings from the DECC study could validate this novel risk assessment tool, providing a comprehensive, non-invasive, potentially inexpensive, and valid method of assessing susceptibility to dental caries, as outlined by the AAPD, that is sorely needed to combat rising ECC rates (Pediatric Oral Health Research and Policy Center, 2012). Utilization of early risk assessment methods to identify children at highest risk of ECC and initiation of preventive oral health treatments are measures that hold the potential to drastically reduce future costs associated with this devastating chronic disease of childhood (Berg & Stapleton, 2012). The MSB risk assessment tool may be able to fill the current void in effective ECC risk assessment to promote the management and reduction of this highly prevalent infectious oral disease of childhood.

Additionally, findings from the DECC study will also contribute to the current body of literature on the utility of MS saliva testing among young children. The relationship between anthropometric measures (BMI/age percentiles) and dental caries will also be further explored within the study population. Furthermore, findings from the DECC study will contribute to the growing body of literature on specific dietary intake patterns and food cariogenicity as they relate to caries risk in young children. Lastly, findings from the DECC study will provide insight into the utility of MSB as a promising tool for behavior change interventions related to both oral, and potentially, general health as well.

1.6 – Scope and Delimitations

The DECC study was designed as a cross-sectional study; therefore participants were not followed over a period of time to evaluate the effect of the intervention on caries outcomes. The data collected utilizing this methodology provides a “snapshot” of current oral health conditions thus allowing for the evaluation of correlations between current behaviors and evidence of ECC risk. As a primary aim of the DECC study is to evaluate and validate the utility of MSB as an effective ECC risk assessment tool for the identification of high-risk children, concurrent data collection on risk factors and oral health measures was deemed appropriate. The collection of data on both physical and behavioral measures related to ECC allows for evaluation of the validity of MSB as a comprehensive assessment tool.

Because of the chosen cross-sectional study design, the DECC study is not intended to assess long-term behavior modification. However, if the results of the DECC study show that the MSB tool is a useful ECC risk assessment tool, future research utilizing MSB can be designed to evaluate effectiveness of MSB as a long-term behavior modification intervention tool for the reduction of ECC.

Although MSB was designed to be implemented on a portable electronic device (iPad), literature on the use of tablet devices in health interventions was not reviewed in the design of the DECC study. Literature on utilization of advanced technology in public health interventions was reviewed during the development of MSB under the parent study (Bio-Behavioral Chronic Disease Management by Families of Young Minority Children), but was not essential for the purposes of this study. The DECC study was not designed to evaluate the impact of intervention and education delivery via electronic device; it was instead intended to evaluate the software program (MSB) itself.

Lastly, the target population for the DECC study was chosen in part due to the fact that MSB was designed to be utilized within a predominantly minority, low-income, Spanish speaking population. MSB incorporates tailored and culturally appropriate content for this target population. Moreover, the DECC study was designed to target this population specifically because ECC has been shown to disproportionately affect children in underserved populations, with some of the greatest disparity observed in low socioeconomic and immigrant populations (Cruz et al., 2009; Francisco et al., 2007; Pieper et al., 2012; Touger-Decker & van Loveren, 2003). Therefore the DECC study was not designed to validate MSB for widespread use with general populations; however, MSB can be tailored to be appropriate for future application with other diverse populations.

1.7 – Definition of Key Terms

Table 1.1

Definition of Key Terms

Term	Definition
Caries Prevalence	Prevalence refers to the presence of any carious lesions severe enough to cause cavities or be restored with fillings (Norman Tinanoff & Reisine, 2009).
Cariogenic	Foods and beverages containing fermentable carbohydrates that can cause a decrease in salivary pH to < 5.5, causing damage to the enamel via demineralization when in contact with microorganisms in the mouth.
Cariostatic	Foods and beverages that are not metabolized by microorganisms in plaque and do not subsequently cause a drop in salivary pH to < 5.5 within 30 minutes.
Concurrent Criterion Validity	A type of validity in which a measurement instrument is correlated with some criterion that is administered at about the same time. This type of validity is often employed when researchers wish to substitute a shorter or more easily administered test for a criterion that is more difficult to measure (Thomas, Nelson & Silverman, 2005).
Deep Sedation	A drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained (American Academy of Pediatric Dentists, 2007).
General Anesthesia	A drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired (American Academy of Pediatric Dentists, 2007).
Dental Caries	A localized, post-eruptive, pathological process of external origin involving softening of the hard tooth tissue and proceeding to the formation of a cavity (World Health Organization, 1962). Caries is an oral infectious disease of the

Term	Definition
	mouth that impacts the integrity of the teeth in which organic acids produced by the metabolism of fermentable carbohydrates by oral microorganisms lead to enamel demineralization and destruction of the tooth structure (Touger-Decker, 2007). Dental *caries* is the disease process that causes cavities (Hirsch, et al. 2012).
dmfs/DMFS [dfs Index] (primary/ permanent dentition)	The extent or intensity of caries attack in a person as measured by the number of decayed (D), missing (M) or filled (F) surfaces (S) (Norman Tinanoff & Reisine, 2009). Owing to the difficulty in differentiating between primary teeth missing due to caries and those missing as a result of the natural exfoliation process, missing teeth may be ignored in some protocols; thus utilizing a **"dfs"** index (Shulman & Cappelli, 2008).
dmft/DMFT [dft Index] (primary/ permanent dentition)	The extent or intensity of caries attack in a person as measured by the number of decayed (D), missing (M), or filled (F) teeth (T) (Norman Tinanoff & Reisine, 2009). The dmft/DMFT indices are used to evaluate prevalence and severity of dental caries in populations (Moynihan & Petersen, 2004). Owing to the difficulty in differentiating between primary teeth missing due to caries and those missing as a result of the natural exfoliation process, missing teeth may be ignored in some protocols; thus utilizing a **"dft"** index (Shulman & Cappelli, 2008).
Early Childhood Caries (ECC)	Previously called baby bottle tooth decay or maxillary anterior caries, ECC is an oral infectious disease that is defined as the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries) or filled tooth surfaces in any primary tooth in a preschool-aged child between birth and 71 months of age (American Academy of Pediatric Dentistry, 2011).
Edentulism	Without teeth; complete edentulism refers to missing all teeth. Partial edentulism refers to missing several teeth.
Fermentable Carbohydrates	Carbohydrates from foods and beverages that can be broken down in the oral cavity (by salivary amylase), via the process of fermentation, providing a substrate for the actions of oral bacteria. Fermentable carbohydrates include free sugars, glucose polymers, fermentable oligosaccharides and highly refined starches (Moynihan & Petersen, 2004; Touger-Decker & van Loveren, 2003).
Mutans Streptococci	Mutans streptococci (MS) are the primary microorganisms associated with early childhood caries and are considered an important predictor of disease (Loesche, 1969; Reisine & Litt, 1993; Tanzer et al., 2001; Norman Tinanoff & Reisine, 2009).
Periodontal	An oral infectious disease involving inflammation and loss of bone and the

Term	Definition
Disease	supporting tissue of the teeth, characterized by inflammation and destruction of the attachment apparatus of the teeth, including the ligamentous attachment of the tooth to the surrounding alveolar bone (Touger-Decker, 2007).
Root Caries	Progressive lesions that are confined to the root surface, or involve the undermining of the cement-enamel junction, but are clinically indicated to be initiated on the root surface.
Severe Early Childhood Caries (S-ECC)	S-ECC refers to "atypical" or "progressive" or "acute" or "rampant" patterns of dental caries (American Academy of Pediatric Dentistry, 2011). In children younger than 3 years of age, any sign of smooth-surface caries is indicative of S-ECC; from ages 3 through 5 years, 1 or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth or a decayed, missing, or filled score of ≥ 4 (age 3), ≥ 5 (age 4), or ≥ 6 (age 5) surfaces also constitutes S-ECC (American Academy of Pediatric Dentistry, 2008; Drury et al., 1999).
Tooth Erosion	The gradual loss of the outside, hard surface of the tooth due to chemical, not bacterial, processes. It is most commonly associated with frequent consumption of acidic beverages or frequent vomiting or regurgitation as occurs with bulimia or gastro esophageal reflux disease.

CHAPTER 2

Literature Review

The following chapter describes the current body of literature related to early childhood caries (ECC) and diet. A discussion of the individual and societal impacts of oral health, as well as disparities and prevalence rates of ECC will be presented. Additionally, the etiology of ECC, diet-related risk factors, and ECC treatments and interventions will be reviewed. Furthermore, a summary of diet and oral health recommendations for children will be presented as well as an overview of ECC risk assessment tools.

2.1 - Oral Health Impact and Consequences

Once established, oral diseases are often chronic, progressive, lifelong afflictions that, due to the effects of cumulative disease progression, result in lasting health consequences throughout the lifespan (Cruz et al., 2009; Milgrom, Zero, & Tanzer, 2009; Moynihan & Petersen, 2004). Early Childhood Caries (ECC) is one such disease. ECC is an infectious disease of the oral cavity, of great consequence, affecting an alarming number of young children. ECC affects approximately 28 percent of children 2 to 5 years of age (Dye, et al., 2007). Of these children, nearly 11 percent of two year olds, 21 percent of three year olds, 34 percent of four year olds, and 44 percent of five year olds have frank cavitations, with an even greater number exhibiting earlier signs of the disease (H. Iida, et al., 2007).

A morbidity and mortality pyramid, successively representing the increasing severity of ECC consequences, was proposed by Casamassimo, et al. (2009) (Figure 2.1 –ECC Morbidity and Mortality Pyramid). According to this model, less severe consequences of ECC might be those related to the indirect costs associated with ECC (e.g., inappropriate use of over-the-counter pain medication, days missed from work), followed by family associated morbidity (e.g., eating and sleeping dysfunction, cost of travel and childcare), followed by hospital costs (e.g., misuse of emergency departments, morbidity associated with anesthesia), and culminating in death in the most severe cases. This figure provides a concise overview of the multitude of consequences associated with this disease, which exert an impact at the individual, family, and greater community levels. Many of these consequences associated with ECC will be discussed in the sections that follow.

2.1.1 – Systemic health consequences. Commonly referred to as, “baby bottle tooth decay”, ECC is defined as the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries) or filled tooth surfaces (dmfs) in any primary tooth in a preschool-aged child between birth and 71 months of age (American Academy of Pediatric Dentistry, 2011). Children suffering from ECC may experience physical impairments, including mouth pain, tooth loss, malocclusion, chewing difficulties, and speech problems, and may also experience difficulty sleeping, social development delays and attention deficit (Adams, Hyde, & Gansky, 2009; "Oral health in America: a report of the Surgeon General," 2000). There has also been some evidence of developmental difficulties, with disparate reports of an association with failure to thrive prior to treatment for ECC (G. Acs, et al., 1992). Due to these health consequences, ECC can result in impaired growth and development of children, and greatly elevated risk of future oral health problems, including caries in the permanent dentition (American Academy of Pediatric Dentistry, 2011; "Oral health in America: a report of the Surgeon General," 2000; Norman Tinanoff & Reisine, 2009; Vania et al., 2011).

Figure 2.1. ECC Morbidity and Mortality Pyramid. A proposed model of early childhood caries morbidity and mortality representing the relatively low rate of mortality and high rate of morbidity associated with this disease (Casamassimo, et al., 2009).

Maintaining proper health of the oral cavity, and the various structures of which it is composed, is integral to maintaining overall systemic health (Berg & Stapleton, 2012; "Oral health in America: a report of the Surgeon General," 2000). The relationship between oral and systemic health has been well established in the literature, but additional correlations continue to emerge. In response to emerging evidence on the relationship between oral and systemic health, and the recognition of alarmingly high prevalence rates, the United States Surgeon General issued a report declaring, “America is in the midst of an oral health crisis” ("Oral health in America: a report of the Surgeon General," 2000; C. Palmer et al., 2010). Evidence has revealed that a close association between periodontal disease and diabetes, obesity, and cardiovascular disease exists, as well as a strong correlation between several oral diseases and other non-communicable chronic diseases likely resulting from common risk factors associated with their etiology (Arora et al., 2011; Genco et al., 2005; Moynihan & Petersen, 2004; C. Palmer et al., 2010).

If disease progression and risk of these associated comorbidities are to be diminished, ECC and other chronic oral health diseases must be effectively treated in a timely manner. If left untreated, oral infectious diseases can exert a damaging effect on systemic health. Oral infectious diseases have been indicated in a number of serious health conditions, as previously indicated, and even death in rare cases (Berg & Stapleton, 2012; Casamassimo et al., 2009; Moynihan & Petersen, 2004; "Oral health in America: a report of the Surgeon General," 2000; Otto, 2007; C. Palmer et al., 2010).

2.1.2 – Impact on nutrition status. In addition to the risk of systemic infection and chronic disease, poor oral health in childhood can result in profound nutrition-related health consequences. Scientific evidence suggests that there is a lifelong synergy between nutrition and oral health whereby each one both influences and is influenced by the other; nutrition influences oral health by impacting development and integrity of the oral cavity, and oral health influences nutrition by affecting functional ability to eat (Touger-Decker, 2007). Oral health issues can result in decreased appetite and diminished ability to eat, thus placing an individual at high risk for poor nutrition status (Colares & Feitosa, 2003; B. L. Edelstein et al., 2006; Mofidi et al., 2009; C. Palmer et al., 2010; Papas et al., 1989). The mouth pain and discomfort caused by ECC can lead to avoidance of healthful foods as well as a lack of desire to eat and inability to properly masticate food, which can result in reduced caloric intake and/or inappropriate food choices (Gussy, Waters, Walsh, & Kilpatrick, 2006; R Harris, Nicoll, Adair, & Pine, 2004; C. Palmer et al., 2010; Vania et al., 2011).

ECC and other oral health problems, which contribute to inadequate or inappropriate nutrient intake, may result in failure to thrive in children due to increased preference for consumption of easily masticated foods (G. Acs, et al., 1999; Gussy et al., 2006; R Harris et al., 2004; C. Palmer et al., 2010; Vania et al., 2011). Such foods, which are often low in nutritional quality, such as cakes and pastries, are preferentially consumed instead of nutrient-dense, fiber-rich foods, such as fresh fruits, vegetables, and high fiber grains (Gussy et al., 2006; R Harris et al., 2004; C. Palmer et al., 2010). Ultimately, poor nutrient intake in childhood resulting in compromised nutrition status may result in unintentional weight loss, impaired wound healing, decreased resistance to infections, impaired cognitive development, poor oral health in adulthood, and poor general health (Gussy et al., 2006; C. Palmer et al., 2010; Papas et al., 1989).

As a result of the strong potential for ECC to exert a significant impact on nutritional status, several studies have investigated the relationship between ECC and weight status. The findings from these studies have been conflicting, with several reporting a positive association between the two (Sharma & Hedge, 2009; Trikaliotis, et al. 2001) an inverse relationship (Macek & Mitola, 2006; Vania, et al., 2011; Werner, Phillips, & Koroluk, 2010) and several reporting no relationship at all (Chen, et al., 1998; D'Mello, et al., 2011; Norberg, et al., 2012; Pinto, et al., 2007; Sheller, et al., 2008). The majority of studies on weight status and ECC evaluate weight by calculating body mass index (BMI) percentiles, however, Costacurta, et al. (2011) explored this association using both BMI and dual energy x-ray absorptiometry (DEXA). Since DEXA is considered an accurate assessment measure of percent body fat, it is believed to be a better indicator of weight status than BMI calculation. Coscatura, et al. (2011) found a significant association with overweight/obese children, as defined by percent body fat (evaluated via DEXA), and caries index; whereas no significant association was found between BMI classification and caries. Furthermore, since they found significant discrepancies between weight classification via BMI and DEXA results, Coscatura, et al. (2011) reported that BMI might misclassify children's adiposity. Therefore, previous studies that relied on BMI as an indicator of weight status, may have incorrectly classified children, thereby potentially leading to spurious findings. This may provide an explanation for the inconsistent findings from studies evaluating the association between ECC and child weight.

2.1.3 – Quality of life. Children with poor oral health resulting from ECC may have difficulty carrying out basic activities of daily living, including playing, eating and sleeping because of pain, and may also experience a delayed ability to speak and distraction from learning (Berg & Stapleton, 2012; Colares & Feitosa, 2003; B. L. Edelstein et al., 2006; "Oral health in

America: a report of the Surgeon General," 2000). ECC has been found to cause significant childhood distress, increased utilization of prescription antibiotics, severe pain, sepsis, and sleep loss (Arora et al., 2011). As a result of the impact of ECC on the daily life of a child, significant impairments in quality of life have been observed (American Academy of Pediatric Dentistry, 2011; Low, Tan, & Schwartz, 1999). Oral health has been identified as an important determinant factor for quality of life because maintenance of the craniofacial complex (comprised of the tissues of the oral cavity and face) allows for social interactions and proper nutrition through the ability to speak, smile, kiss, touch, express emotions, smell, taste, chew, and swallow (Moynihan & Petersen, 2004; "Oral health in America: a report of the Surgeon General," 2000). Damage to the craniofacial complex may significantly impact the way one views her/himself and the way others view them, which can contribute to decreased self-esteem and well-being ("Oral health in America: a report of the Surgeon General," 2000). The experience of pain, difficulty eating and chewing, embarrassment about the shape of teeth or missing, discolored or damaged teeth may contribute to the psychosocial impact of ECC, further contributing to diminished quality of life (Moynihan & Petersen, 2004).

The effect on quality of life can also be seen in evaluations of caregivers' perceived impact of ECC experience on their children. A study which evaluated perceived effects of ECC among parents of children enrolled in a Head Start program, found that parents noted pain, trouble sleeping, poor nutrition, crying, bad moods, fear of dentists, and negative emotional consequences (for themselves and their children) as consequences of childhood tooth decay (Mofidi et al., 2009). Another study which evaluated the impact of ECC on quality of life, examined the perceptions of caregivers (N = 77) of children 4 years of age in Brazil (Colares & Feitosa, 2003). This study found that caregivers of children with caries stated that their children were ashamed to smile (31%), had problems eating (49%), and were more likely to be absent from school (26%), thus contributing to the evidence that caries impacts factors related to quality of life (Colares & Feitosa, 2003). Furthermore, a recent study by Kramer, et al. (2013) evaluated caregiver perception of children's quality of life, and found that the prevalence of experiencing a negative impact on quality of life was nearly three times higher for children with caries compared to those without. Quality of life has been shown to improve, however, after the receipt of dental treatment. A study by Malden, et al. (2007) evaluated parental perception of oral health-related quality of life for children undergoing restorative dental treatment under general anesthesia. This study found significant improvements in oral health-related quality of life following treatment for extensive dental caries, among this population of children who had been experiencing long-term negative consequences of caries, including pain, lack of sleep and diminished ability to eat (P.E. Malden, et al., 2007).

2.1.4 – Academic achievement. Related to its impact on quality of life, oral health during childhood has been indicated as an influential factor in school performance. Evidence suggests that children suffering from poor oral health are more likely to have poor school performance compared to children with good oral health (Blumenshine, Vann, Gizlice, & Lee, 2008; Low et al., 1999; Ng, 2011). Contributing to poor school performance is the fact that children with ECC have been found to have a diminished ability to learn, impaired cognitive function, delayed social development, and attention deficit (Adams et al., 2009; American

Academy of Pediatric Dentistry, 2011; "Oral health in America: a report of the Surgeon General," 2000). The negative impact on school performance may also be related to lost school hours due to poor oral health, as ECC has been found to restrict activities in school and home, resulting in millions of lost hours each year (Colares & Feitosa, 2003; Gift, Reisine, & Larach, 1992; Moynihan & Petersen, 2004). In an evaluation of data from the 1989 National Health Interview Survey, Gift, et al. (1992) found that children lost more than 51 million hours of school as a result of dental visits or oral health problems. Another contributing factor to poor school performance associated with ECC is that children with oral health problems are less likely to participate in the classroom, and are more likely to have speech problems, which may further limit participation (Mofidi et al., 2009). For preschool aged children, lost hours are measured in number of "bed" or "restricted activity" days. As a result of dental problems, nearly four percent of children under the age of five experience *bed* days (days which are spent in bed) and over nine percent have *restricted activity* days (in which they cut down on daily activities) (Adams, Hendershot, & Marano, 1996). Due to its detrimental impact on young children's quality of life, incredibly high prevalence, and potential for increasing their risk of caries in the permanent dentition ECC is viewed as one of the most serious and costly health conditions affecting young children (Norman Tinanoff & Reisine, 2009).

2.1.5 – Economic impact. Although the physical and emotional costs described above are immeasurable, the economic cost and burden of ECC can be quantified. Dental repair for ECC is expensive, and often requires extensive restorative care and extraction of affected teeth (Norman Tinanoff & Reisine, 2009). Because ECC is a disease of early childhood, children in need of dental restorations to treat ECC often lack the ability to cope with necessary procedures (Norman Tinanoff & Reisine, 2009). This “lack of cooperative ability” is a consequence of their young age and developmental stage; thus children undergoing restorative treatment for ECC often require deep sedation or general anesthesia (Berkowitz, 2003; Norman Tinanoff & Reisine, 2009; Yoon, Smaldone, & Edelstein, 2012). Compounding the economic burden of care is the fact that very young children with ECC may be unable to adequately verbalize complaints of oral discomfort or pain. As a result, ECC is often treated in emergency care settings, because children suffering the painful physical consequences of ECC are frequently brought into hospital emergency rooms (ERs) by caregivers seeking immediate treatment for non-traumatic dental conditions (American Academy of Pediatric Dentistry, 2011; Norman Tinanoff & Reisine, 2009). A study by Nalliah, et al. (2010) investigated the use of ERs for the treatment of dental caries during 2006. This study found that there were a total of 330,757 ER visits attributable to caries, resulting in $110 million in charges. The majority of children presenting to ERs for caries-related care were covered under Medicaid, which accounted for over half of all visits (Nalliah, et al. 2010). The economic burden of ECC treatment on the Medicaid system is also evident in evaluations of Medicaid expenditures in California, where merely 5 percent of children who receive restorative dental care for ECC account for 35 percent of dental expenditures (Reforming States Group, 1999). Another recent study Okunseri, et al., (2011) evaluated the use of ERs and physicians’ offices in Wisconsin by Medicaid enrollees for treatment of non-traumatic dental conditions. This study found that nearly four thousand children under the age of 10 years were brought to hospital ERs or physicians’ offices for care instead of a dental office.

The reliance on ERs and physicians' offices for dental care places a significant burden on these institutions, as well as the Medicaid system, and highlights the issue of inadequate access to dental care experienced by many Medicaid enrollees. The majority of dentists are located in affluent and suburban areas, where their patients reside, thereby leaving one-third of cities *Dental Shortage Areas* as designated by the Department of Health and Human Services (DHHS) (Reforming States Group, 1999). Furthermore, the poor reimbursement structure and policies associated with processing Medicaid claims discourage dentists from participating in the program; thereby leaving many Medicaid recipients with limited access to dental professionals. Since emergency care is unlikely to treat underlying oral health diseases, many patients who seek emergency care in lieu of specialized dental treatment, experience a relapse in their oral health condition and ultimately seek subsequent treatment; continuing the cycle of expensive and insufficient care.

Restorative treatment for Severe Early Childhood Caries (S-ECC) is the leading cause of childhood hospitalization for treatment under general anesthesia (Sheller et al., 1997). S-ECC refers to "atypical", "progressive", "acute", or "rampant" patterns of dental caries (American Academy of Pediatric Dentistry, 2011). S-ECC is formally defined as any sign of smooth-surface caries in children younger than 3 years of age; from ages 3 through 5 years, 1 or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth; or a decayed, missing, or filled surfaces (dmfs) score of ≥ 4 (age 3), ≥ 5 (age 4), or ≥ 6 (age 5) (Drury et al., 1999).

Traditional restorative treatment for oral disease is very costly, and has been identified as the fourth most expensive class of disease to treat in most industrialized countries (Moynihan &

Petersen, 2004). Data on ECC prevalence and treatment in Australia confirm the costly nature of dental caries, identifying it as the most costly diet-related chronic disease in the nation, ahead of coronary artery disease, overweight and/or obesity, hypertension, and diabetes (Arora et al., 2011). The estimated cost for restorative dental treatment among children in the United States is over $2 billion annually, making it one of the single most expensive diseases of childhood (Berg & Stapleton, 2012).

An early assessment of ECC treatment costs by Kelly & Bruerd in 1987 found that the cost of restorative treatments ranged from $700 to $1000, if hospitalization is needed (Weinstein, 1998). A later evaluation of ECC treatment costs suggested values from $408 to $1725, and a third evaluation added that treatment of ECC involving general anesthesia can increase the total cost to as much as $6000 (Francisco et al., 2007; Norman Tinanoff & Reisine, 2009; Weinstein, 1998). The utilization of general anesthesia and methods of deep sedation are not only costly, but they are also potentially dangerous. Research on the possible neurotoxicity of various general anesthetics has been inconclusive, but several rodent and non-human primate studies have suggested there may be a long-term neurodevelopmental and behavioral risks associated with their use; prospective studies are currently underway to explore this association in humans (Sun, L., 2010). Application of these sedation techniques thus presents the potential for sedation-related risks, including anesthesia-induced neurotoxicity, which may contribute to increased hospital-related costs of treatment (Yoon et al., 2012).

The per-child cost of ECC treatment is thus extremely expensive. Since ECC disproportionately affects families with low socioeconomic status, and many families lack adequate oral health care insurance to cover the costs accrued, the financial burden of ECC restorative treatment can be overwhelming and often impossible to manage for parents of children with ECC. Many families are uninsured or underinsured with little, if any, coverage for dental health services. Despite the expansion of public dental programs to provide families with support for dental services, children in these families do not receive nearly as much dental care as children with private dental insurance (Edelstein & Chinn, 2009). Twenty six percent of children receive public dental insurance; however, statistics on dental care utilization reveal that in 2004, 53 percent of children with private insurance visited a dentist, compared to only 34 percent of children with public insurance coverage and 28 percent of uninsured children (Edelstein & Chinn, 2009). This may be related to the fact that in addition to the direct costs of restorative dental treatment, families must consider the added cost of lost work hours as a result of taking their child to the dentist or hospital, which was a noted concern related to perceived impact of ECC among low-income parents (Mofidi et al., 2009).

The financial impact of ECC does not end after restorative treatment. One of the many known consequences of ECC, which continues to affect children long after treatment, is the increased risk of new carious lesions in both primary and permanent dentition (American Academy of Pediatric Dentistry, 2011). There is a high relapse rate after treatment for ECC; and among children treated for S-ECC, greater than 50 percent experience new carious lesions post-treatment, with approximately 40 percent reported within the first year (Almeida et al., 2000; Amin, Harrison, & Weinstein, 2006; Berkowitz, 2003; Weinstein, 1998). Restorative treatments used to repair the tooth structure and extraction of decayed teeth are treatments that do not stop or reverse the caries disease process, and restorative treatments of tooth surfaces have a finite life span (Alfano et al., 2001; American Academy of Pediatric Dentistry, 2011/2012).

Since the underlying disease process is not eradicated by traditional treatment methods for ECC, the disease continues to affect the child after these costly treatments are employed. The prevalence of ECC increases throughout adulthood, which may be a partial explanation for the alarming rates of caries among adults ("Oral health in America: a report of the Surgeon General," 2000). More than 90 percent of adults between the ages of 20 and 64 years have experienced tooth decay (Centers for Disease Control and Prevention, 2009; Bruce A Dye et al., 2007). This number is highly significant, as caries exerts a tremendous impact on overall health and wellbeing, as previously detailed. Additionally, dental caries is a major cause of tooth loss in the United States, which further contributes to oral care costs as a result of increased need for restorative treatment, dentures, and treatment of nutrition-related diseases resulting from the ensuing malnutrition often associated with edentulism (R Harris et al., 2004). Unless disease progression is halted, caries may ultimately result in tooth loss, altering ones ability to chew. Individuals, who are left partially or fully edentulous, are at increased risk of malnutrition and unintentional weight loss due to impaired ability to eat.

The traditional methods of caries treatment, commonly referred to as the “drill and fill” approach to ECC management, is not economically sustainable for states, families, and taxpayers (Berg & Stapleton, 2012). The United States spends a considerable amount of money on health care, including oral care, with over $7000 spent per person in 2006; more than twice the average of 29 other developed countries (*National health expenditures aggregate, per capita amounts, percent distribution, and average annual percent growth, by source of funds: selected calendar years 1960–2007*, 2008). The United States also has the fastest growing rates in health care spending, likely related to the fact that nearly 1 out of every 2 adults had at least one chronic illness in 2005, with this number continuing to rise (Wu & Green, 2000). The costs associated with ECC treatment places a tremendous financial burden on third-party payers (i.e., Medicaid, State Children's Health Insurance Program) as well as on parents, many of whom are among the least likely to be able to afford it (Berkowitz, 2003).

Efforts to curb these rising health care costs through effective disease prevention and management must be identified. A study by Hirsch, et al. (2012) used computer simulations to investigate the potential reduction in caries experience and related costs that could be achieved through employment of various ECC interventions. The interventions under review were fluoride application, limiting maternal transmission of cariogenic bacteria, using xylitol, clinical treatment, motivational interviewing, and various combinations of these methods. This study found that use of interventions targeting young children (2-4 years of age) at the highest risk of caries would exert the greatest benefit in cost and disease reduction. Moreover, combined interventions that target multiple stages of caries disease development may be most effective.

Another study on the use of ECC interventions versus traditional disease treatment focused on the benefits of a disease management approach (Ng, M.N., et al., 2012). Rather than viewing treatment for ECC as simply restorative, surgical, and informational, this quality improvement intervention used a disease management approach, which incorporated use of an ECC risk assessment tool, health provider scripts, and educational handouts. This disease management intervention resulted in a significant reduction in rates of new cavitation, pain and surgical referrals over historical controls; thereby demonstrating that disease management may be a feasible approach to ECC care, and an avenue for significant cost savings and improved patient outcomes.

Lastly, a study by Zavras, Edelstein, & Vamvakidis (2000) evaluated the cost benefit of using microbiological screening tests as a method of caries risk screening for children 1-3 years of age. The findings from this study support the use of screening for mutans streptococci (MS), a cariogenic bacteria strongly associated with caries progression, as an effective and economic means of early identification of children at high risk for caries. This study concluded that a cost savings of over 7 percent could be achieved for toddlers screened for MS compared to those receiving traditional caries management. Current research therefore supports the utilization of early risk assessment methods to identify children at highest risk of ECC, and initiation of preventive oral health treatments, as measures that may drastically reduce future costs associated with this prevalent chronic disease of childhood (Berg & Stapleton, 2012).

2.2 - Early Childhood Caries Prevalence

Since the late 1940s, most developed countries have experienced a significant decline in overall rates of dental caries. The decline in dental caries has been largely attributed to widespread efforts to improve oral health via increased access to fluoridated oral dentifrices (toothpaste) and fluoridation of municipal water supplies and (Fisher-Owens et al., 2007; 2010; Pieper et al., 2012). Despite this observed decline, the prevalence of dental caries remains unacceptably high and continues to pose a major public health problem (Moynihan & Petersen, 2004). Perhaps most disconcerting, is the fact that caries rates among children, 2-5 years of age, appear to be increasing while rates within most other age groups have remained fairly stable (Dye, et al., 2007).

Dental caries affects over 90 percent of adults in the United States, and is considered the most prevalent disease of children, affecting over one quarter of preschool children, and disproportionately affecting children in underserved populations (Cruz, Chen, Salazar, & Le Geros, 2009; Dye, et al., 2007; Francisco et al., 2007; Pieper et al., 2012; Touger-Decker & van Loveren, 2003). Moynihan & Petersen, 2004). Although there has been an overall decline in the prevalence and severity of dental caries, there has not been a reduction in ECC (Beltran-Aguilar et al., 2005). There is strong evidence to suggest that the observed reduction in dental caries rates has not only been halted, but that rates are actually increasing, particularly among children under the age of 5 years who are affected by ECC (Moynihan & Petersen, 2004; "Oral health in America: a report of the Surgeon General," 2000; 2010; Norman Tinanoff & Reisine, 2009).

Data from the National Health and Nutrition Examination Survey (NHANES) show that dental caries rates have increased substantially among the nation’s preschool-aged children. Rates of dental caries rose from 40 percent in children aged 2 to 11 years in the 1988-1994 survey, to 42 percent in the 1999-2004 survey; this increase is largely attributable to the increase among those children aged 2 to 5 years, which rose from 24 to 28 percent (Bruce A Dye et al., 2007). Among these children, it is estimated that approximately 11 percent of two year olds, 21 percent three year olds, 34 percent of four year olds, and 44 percent of five year olds have frank dental cavitations, with an even higher percentage of children (not included in these estimates) exhibiting earlier signs of ECC, such as white spot lesions or enamel decalcification and accumulation of plaque (Bruce A Dye et al., 2007; Iida, Auinger, Billings, & Weitzman, 2007). These estimates are based on criteria for identification of frank cavitations set by the Centers for

Disease Control and Prevention (CDC), which requires an explicit level of cavitation beyond what clinicians often use, to meet the definition; thus, these are likely conservative estimates of prevalence rates.

Moreover, the great majority of children afflicted by ECC have untreated disease (Norman Tinanoff & Reisine, 2009). According to 1994-2004 NHANES data, 73 percent of preschool-aged children with ECC in the United States remain untreated (Bruce A Dye et al., 2007). The high percentage of children living with untreated ECC, poses a significant public health threat. As was discussed earlier in this chapter, ECC has a profoundly negative impact on the quality of life of children suffering from this disease, and greatly increases their risk for later development of caries in the permanent dentition; thus, ECC is considered one of the most serious and costly health conditions among children (Norman Tinanoff & Reisine, 2009).

2.3 - Oral Health Disparities

As is often revealed in evaluations of disease prevalence and severity, research has shown that there are significant disparities in ECC among specific segments of the population. ECC has been identified as the leading nutrition-related oral disease found in young children and the socially disadvantaged (Alvarez, 1995; Vargas & Ronzio, 2006). ECC disproportionately affects children in underserved populations, with some of the greatest disparity observed in low socioeconomic and immigrant populations (Cruz et al., 2009; Francisco et al., 2007; Pieper et al., 2012; Touger-Decker & van Loveren, 2003).

2.3.1 – Race/ethnicity and immigration status. The United States is a racially and ethnically diverse country that has attracted, and continues to attract, a large number of foreign-born immigrants. The 2010 United States Census revealed that the United States population has become more racially and ethnically diverse over time, with over one third of the population belonging to a racial or ethnic minority group (Humes, Jones, & Ramirez, 2011). The Census also found that over half of the nation's population growth between 2000 and 2010 could be attributed to an increase in the Hispanic population, which grew by 43 percent during this time (Humes et al., 2011). A cross-sectional study of 1318 immigrants in New York City confirmed this population trend, suggesting that the racial and ethnic diversification of the United States population has been largely driven by immigrants from Latin America and the Caribbean (Cruz et al., 2009). Additionally, this study noted that more than 56 percent of the population in New York City consists of foreign-born individuals and their children (Cruz et al., 2009). The high percentage of racial and ethnic minorities in the United States, and particularly within New York City (where the DECC study was conducted), is of great importance in the discussion of ECC prevalence.

While prevalence rates of ECC are high for all children, rates are often alarmingly elevated among immigrant and racial/ethnic minorities (Dietrich, Culler, Garcia, & Henshaw, 2008; Bruce A Dye et al., 2007; Weinstein, 1998). Research has found that both immigrant adults and immigrant children have higher rates of dental caries than natives of similar age; this is particularly notable among preschool-aged children (Cruz et al., 2009). Children with immigrant backgrounds living in the United States have been found to exhibit dental caries rates three times higher than non-immigrant children (American Academy of Pediatric Dentistry, 2011/2012). One study of immigrants in New York City found that Hispanic and Black Caribbean immigrants exhibited the highest levels of dental caries (Cruz et al., 2009).

Racial disparities in dental caries can be clearly observed in an evaluation of prevalence rates among children 2-11 years old in the United States, which revealed approximately 55 percent of Mexican American, 44 percent of African American and only 39 percent of non-Hispanic White children exhibited frank cavitations (Berg & Stapleton, 2012; Bruce Dye, et al., 2007; B. L. Edelstein, 2008; Kawashita et al., 2011). It should be noted that national data from the NHANES study were collected on several oversampled subgroups of the population in order to provide reliable estimates of their health and nutritional characteristics (Vital and Health Statistics, 1992). However, data were not sufficiently captured for all potential racial/ethnic groups, owing to budgetary and feasibility constraints. Thus, the NHANES data presented regarding racial disparities related to oral health are not representative of all Hispanic/Latino populations; NHANES only provides statistically reliable estimates of Mexican-Americans as a subgroup of the larger Hispanic/Latino population. National data regarding ECC rates among Native American and Alaskan Native children are also quite alarming, with these children suffering from ECC rates five times the national average (Indian Health Service, 1999). This data suggest that ECC affects nearly all Native American and Alaskan Native children, with nearly two-thirds affected by S-ECC (Indian Health Service, 1999).

Not only are immigrant and minority children more likely to suffer from dental decay than White children, their decay is often more severe (Berg & Stapleton, 2012). Moreover, a study evaluating interview data on parental perceptions of oral health status revealed that Hispanics were twice as likely as non-Hispanic whites to report their children's oral health as fair or poor, even after controlling for socioeconomic status (Dietrich et al., 2008). Another study found that although 76 percent of White parents report that their children's "teeth are in excellent or very good condition," only 61 percent of African American parents and 47 percent of Hispanic parents report the same (US Department of Health and Human Services, 2003). These findings may be particularly notable given the fact that parental perceptions of health status tend to underreport clinically determined oral health needs; thus, although their parents are reporting less than positive health statuses, these children may be at even higher risk of oral health problems than their parents realize (Dietrich et al., 2008).

Culture exerts a myriad of influences at the individual, familial, and greater community levels, which may partially explain racial and ethnic disparities (Fisher-Owens et al., 2007). Immigrants move to the United States with culturally-specific beliefs and attitudes regarding oral healthcare, dietary practices, behaviors, and values, which may influence their oral health outcomes (Cruz et al., 2009). Oral health disparities are likely influenced by such culturally specific beliefs and values, as well as previous experiences with oral health care that may be unique to specific cultural and minority populations.

Ethnic minorities and new immigrants to the United States experience oral health disparities for a variety of reasons, one of which may be cultural differences in the way health care providers interact with racial and ethnic minorities (Norman Tinanoff & Reisine, 2009). Research has found that Hispanic children receive routine dental care at lower rates than non-

Hispanic White children (Soni, June 2011). Additionally, international studies confirm that immigrants and their families utilize dental services less often than non-immigrants (Adair, 2004). This may be related to a combination of cultural differences, socioeconomic disparities, and past health care experiences that influence utilization of dental care. Since poverty rates are high among children and there is a growing percentage of children who are both minority and low income, cost of dental treatment likely poses a significant barrier to receiving appropriate care (Edelstein & Chinn, 2009). There is also evidence to suggest that health care providers interact differently with minority patients and that there are cultural differences in the way minority patients view disease etiology, course, and outcomes, as well as their level of trust and access to social resources (Norman Tinanoff & Reisine, 2009). If the relationship between lower utilization of dental services and higher rates of caries experience among racial/ethnic minorities continues, these health disparity rates are expected to worsen as with shifting demographic and economic trends (Edelstein & Chinn, 2009). Therefore, targeted interventions to reduce the impact of health disparities on racial/ethnic minorities must be developed promptly.

Lack of information among immigrants, a low standard of education, and linguistic and cultural communication challenges with healthcare providers add to the challenges many immigrants face (Pieper et al., 2012). Despite these challenges, research has suggested that in highly diverse, multicultural neighborhoods, such as those found in New York City, language and communication barriers pose less of an obstacle to oral health information and care than culturally influenced behaviors and past experiences (Cruz et al., 2009).

The neighborhood environment in which one resides has the potential to exert a significant influence on health outcomes. The level of poverty, stability, safety, cohesion, and support within a neighborhood environment can all help to ameliorate or exacerbate risks to one's health (Fisher-Owens et al., 2007). A study by Bramlett, et al., (2010) evaluated a multilevel conceptual model of children's oral health, which incorporated 22 domains at four levels of influence: child, family, neighborhood and state. The study found that there were significant relationships between children's oral health and several domains at each of the four levels. Although the child and family domains exerted the greatest influence on child oral health, four of the community-level factors (neighborhood- or state-level) had significant effects, including: social environment, social capital, physical safety, and physical environment (M.D. Bramlett, et al., 2010). This study therefore supports the highly influential impact of one's environment on personal oral health outcomes.

Culture also exerts a significant influence on nutrition-related beliefs and behaviors. However, immigration to a new country and acculturation to the prevailing ethos may cause a shift in nutrition-related behaviors and beliefs. Immigrants' country of origin, length of stay in the United States, and age at immigration all influence their diet and oral health behaviors and thus impact their oral disease risk (Cruz et al., 2009). Research has indicated that lengthier periods of acculturation are associated with better oral health outcomes, and that more acculturated Hispanics in the United States utilize dental care more often (Fisher-Owens et al., 2007). Increased utilization of oral health services is a positive outcome of acculturation, but acculturation may also have a negative impact on oral health. Disparities in ECC prevalence and severity rates among immigrants may be partially explained by alterations in traditional nutrition-related behaviors along with acculturation and adoption of dietary norms in the United States (Mobley, Marshall, Milgrom, & Coldwell, 2009). For example, immigrants may shift from a diet high in fiber-rich foods that is related to low dental caries risk, to one more commonly consumed in the United States, which is much higher in refined carbohydrates and thus poses a higher risk of dental caries (Cruz et al., 2009; Touger-Decker & van Loveren, 2003).

Diet-related disparities exist among different segments of the population, including differences in dietary intake, behaviors, and patterns, which are related to differences in dietary quality and health outcomes (Satia, 2009). For example, a study exploring caries risk factors in toddlers, found that dietary factors and health beliefs differed based on race/ethnicity (M. Fontana, et al., 2011). In this study, a significant predictor of caries among Hispanic participants was consumption of soda between meals, whereas this variable was not significant for either African American or Caucasian groups.

Diet-related disparities are often defined by diets high in fat and salt, and low in fruits, vegetables and whole grains; a diet not uncommon in the United States (Satia, 2009). These diet-disparities are not only a result of cultural influence, but are also greatly impacted by socioeconomic status. Lack of availability of quality food, issues of “food deserts” in rural and low income urban neighborhoods, food insecurity, and changing nutrition-related beliefs as a result of acculturation, are all deterrents to healthful eating and thus increase risk for ECC as well as other chronic health conditions, including childhood obesity (Mobley et al., 2009).

2.3.2 – Socioeconomic status. Although disparities in oral health are often discussed on the basis of race and ethnicity, the factors which contribute to observed disparities are often more strongly associated with socioeconomic status than race or ethnicity (Satia, 2009). In the United States, children and ethnic minorities are living in poverty in increasing numbers, thus exacerbating the oral health disparities already observed in these populations (Mobley et al., 2009). It has been shown that poverty rates are associated with dental morbidity, and socioeconomic status has been shown to be a stronger predictor of caries risk in children than in adults (Fisher-Owens et al., 2007). An inverse relationship between socioeconomic status and caries prevalence has been found in studies of children under the age of 6 years (American Academy of Pediatric Dentistry, 2011/2012). Children of high socioeconomic status consistently exhibit a lower rate of caries than children of low socioeconomic status, and the relationship between caries prevalence among preschool-aged children and the socioeconomic status of their parents has been well established (Jablonski-Momeni & Pieper, 2007; Pieper et al., 2012). An evaluation of caries experience from 1999 to 2004 found significant disparities by family income level (represented by percent of federal poverty level (FPL)). Approximately 54 percent of children living in poverty (family income < 100 percent FPL), 49 percent of children in low-income families (family income 100 to 199 percent FPL), and 32 percent of children living in middle and higher income families (family income ≥200 percent FPL) have cavities (B. L. Edelstein, 2008; Kawashita et al., 2011). Furthermore, there are marked disparities in both the extent of disease and the rates of untreated disease between children of varying socioeconomic status. Children 2 to 11 years of age from poor and low-income families are more than twice as likely to have untreated teeth compared to children from higher income families (33 percent of poor children, 28 percent of low-income children, and 15 percent of higher income children have untreated cavities) (B. L. Edelstein, 2008).

The disparities in disease prevalence, severity, and lack of treatment may be related to evidence, which suggests children of low socioeconomic status obtain fewer routine dental examinations compared to children of higher socioeconomic status. Nearly 64 percent of children from high income families reported at least one routine dental examination during the previous year, compared to fewer than 37 percent of children living in poor families (Soni, June 2011). Therefore, it is not unexpected that children of higher socioeconomic status, who receive routine dental care, have fewer untreated cavities. These children are much more likely to receive early intervention for caries than children who do not utilize regular dental services. Children who routinely visit a dentist, at first sign of cavitation, are likely to receive either restorative treatment or guidance regarding/application of fluoridated oral dentifrices to halt progression of decay.

Among low-income children, there are numerous reasons that could be attributed to the observed disparities in dental care utilization rates, one of the most prominent being the multitude of barriers that exist to obtaining oral healthcare (Mofidi et al., 2009). The Institute of Medicine of the National Academies found that in 2008, 4.6 million children did not receive needed dental care because their families were unable to afford it (Berg & Stapleton, 2012; Institute of Medicine of the National Academies, 2011). It has also been hypothesized that oral health disparities on the basis of socioeconomic status may be partially related to low levels of parental education and insufficient adherence to preventive oral health measures (Pieper et al., 2012). Research has found that higher educational level of mothers and greater fluoridated water intake is inversely related to dental caries; mothers with higher levels of education had children with greater fluoride intake and lower likelihood of ECC (Mariri et al., 2003). Additionally, children whose parents had some college education have been found to have higher rates of routine dental examinations than children of parents whose education ended after completion of high school, or whose parents completed less than a high school education (55.7 percent, versus 41.5 percent and 36.2 percent, respectively) (Soni, June 2011).

Oral diseases, particularly ECC, qualify as serious public health challenges. The great majority of ECC is found among a small percentage of the population. Approximately 80 percent of the disease is found in only 20 percent of children, with just 8 percent of 2 to 5 year old children bearing 75 percent of the dental caries experience burden (Berg & Stapleton, 2012; Francisco et al., 2007). The profound disparities described above on the basis of race, ethnicity, immigration and socioeconomic statuses, indicate that the greatest burden of oral health diseases falls upon disadvantaged and socially marginalized populations (Kawashita et al., 2011; Moynihan & Petersen, 2004). This burden appears to be growing, as rates of caries are continuing to increase nationally, particularly among minorities and those living in low-income communities (Adams et al., 2009; Bruce A Dye et al., 2007; Milgrom et al., 2009; Touger-Decker & van Loveren, 2003). The Unites States is continuing to become more racially and ethnically diverse, with studies of population trends in New York City suggesting that demographic shifts in immigrant populations are largely driven by immigrants from Latin America and the Caribbean (Cruz et al., 2009). Since public health systems have a responsibility to control diseases which predominantly afflict the disadvantaged, ECC is considered a significant public health problem that must be addressed through targeted, culturally appropriate interventions (Weinstein, 1998). Efforts to alleviate the cultural, racial, social, educational, environmental, and healthcare service barriers that prevent the most vulnerable segments of the population from obtaining needed care must be addressed in order to improve the oral health of those at highest risk of ECC (B. A. Dye & Thornton-Evans, 2010; "Oral health in America: a report of the Surgeon General," 2000; Touger-Decker, 2007).

2.4 - Early Childhood Caries Etiology

Dental caries is an infectious and transmissible diet-dependent, fluoride-mediated, progressive and highly prevalent disease of the mouth that results in dental cavities. Caries is thus, a complex disease, which cannot be successfully mitigated through the use of a single tactic. If prevalence and severity rates of this disease are to be reduced, a multidimensional approach to disease treatment and prevention must be applied. The etiology of ECC is well known, but its complex, multifactorial nature means that there is no simple causal pathway to target in interventions, thus making the design and implementation of effective interventions challenging (Fejerskov, 2004). The development of ECC is a result of the interplay between a susceptible host (child's tooth), an agent (dental plaque), cariogenic bacteria (most notably, mutans streptococci (MS)), and environmental factors (cariogenic diet, saliva, oral hygiene); thus ECC is considered a "dieto-bacterial" disease moderated by numerous external influences (Fejerskov, 2004; C. Palmer et al., 2010; Tanzer et al., 2001).

2.4.1 – Bacteria. In most diseases, the primary factor in disease development and progression is identification of a susceptible host. In the case of ECC, the susceptible host is an erupted tooth (primary or permanent) in a child under the age of 71 months. The tooth is considered susceptible if there is dental plaque present on the surface of the enamel. Dental plaque is a film that forms on the surface of the tooth, especially along the gum line and chewing surfaces (C. Palmer et al., 2010). Plaque is a type of biofilm composed of a colonized bacteria and salivary protein; biofilm is defined as a "population" or "community" of bacteria living in organized structures at an interface between solid and liquid form (Fejerskov, 2004; C. Palmer et al., 2010). As a biofilm, dental plaque is a sticky substance; as such it attracts and adheres endogenous oral bacteria (Fejerskov, 2004; Francisco et al., 2007; Loesche, 1969).

Oral bacteria play an integral role in ECC etiology. ECC is considered an "infectious and transmissible disease" of the oral cavity; thus suggesting that it is caused by a specific microorganism that can be spread to and "infect" an individual (Fejerskov, 2004). Not all microorganisms in residing in the oral cavity are equally capable of fermenting carbohydrates (Fejerskov, 2004). Cariogenic bacteria must be both acidogenic (capable of producing acid) and aciduric (able to survive within an acidic environment). Although there are numerous oral bacteria, mutans streptococci (MS) are the primary microorganisms associated with ECC and are considered an important predictor (Loesche, 1969; Reisine & Litt, 1993; Tanzer et al., 2001; Norman Tinanoff & Reisine, 2009). MS are ubiquitous in populations worldwide, are believed to be highly correlated with the caries process, even at low colonization levels, and are considered a valid marker for cariogenic flora (Fejerskov, 2004; Loesche, 1969; Tanzer et al., 2001).

Colonization of the oral cavity by cariogenic bacteria is necessary for the initiation of the caries process (Norman Tinanoff & Reisine, 2009).

MS colonization of a child's oral cavity is generally believed to be the result of transmission of MS (among other oral bacteria) from the child's primary caregiver (American Academy of Pediatric Dentistry, 2011; Berkowitz, 2003; Douglass, Li, & Tinanoff, 2008; Milgrom et al., 2009). Acquisition of MS most often occurs vertically from primary caregiver (often the mother) through salivary contact (e.g., sharing utensils/drinking cups, pre-chewing food, orally cleansing pacifiers, physical contact) (American Academy of Pediatric Dentistry, 2011; Berkowitz, 2003; Douglass et al., 2008; Fisher-Owens et al., 2007; Milgrom et al., 2009). This transmission pathway was initially identified in studies that found a correlation between maternal and child dental flora. Transmission of MS, particularly at an early age, is most likely to occur when high colonization levels are present in the oral cavity of the primary caregiver (American Academy of Pediatric Dentistry, 2011). Research has shown that children are at increased risk of ECC when their mothers have high levels of MS and have had previous experience with dental caries (Alfano et al., 2001; American Academy of Pediatric Dentistry, 2011). Conversely, lower risk of caries is associated with mothers who have a positive oral health history. They likely have flora that is less pathogenic and may pass this beneficial flora to their children.

Effectiveness of vertical transmission of MS and subsequent colonization and proliferation within the child's oral cavity may be related to several factors, including magnitude of the initial inoculum, frequency of small-dose inoculations and minimum infective dose (Berkowitz, 2003; Law, Seow, & Townsend, 2007). Frequent exposure to maternal saliva has been strongly associated with successful transmission of MS and is thus discouraged; however, some evidence exists to suggest a potential protective effect associated with early maternal transmission of MS (Aaltonen & Tenovuo, 1994). A study of over 400 Finnish children and mothers by Aaltonen and Tenovuo (1994) found that children with high levels of maternal salivary contact had fewer caries and lower levels of MS than children with fewer salivary contacts. The proposed mechanism responsible for these findings was a potential immune-related mechanism, via development of anti-MS immunoglobulins, precipitated by frequent salivary contact (Aaltonen & Tenovuo, 1994; Law et al., 2007). Despite this suggestion, there is little evidence to date which supports a beneficial effect of early MS transmission and frequent salivary exposures, and this effect has not been observed in clinical practice (Law et al., 2007).

Although vertical transmission is believed to be the primary mode of transmission, it is possible for MS to be acquired via horizontal transmission as well (e.g., between other members of the family, or children in daycare) (American Academy of Pediatric Dentistry, 2011; Berkowitz, 2003). This is a significant finding, as many more children are increasingly being cared for by individuals other than parents/primary caregivers, as a result of socio-economic shifts in Western cultures, which may increase potential for acquisition of MS (Berkowitz, 2003).

MS colonization at an early age is an important risk factor for ECC as well as future dental caries, and it is believed that among high-risk populations, colonization likely occurs before 12 months of age (Alaluusua & Renkonen, 1983; Berkowitz, 2003; Thibodeau & O'Sullivan, 1996; Norman Tinanoff & Reisine, 2009). Early oral colonization of MS combined with high-risk feeding practices and behaviors promote the outgrowth of MS (Berkowitz, 2003;

Fejerskov, 2004). High acid tolerance of MS provides a selective advantage over other less acid-tolerant dental flora (J. van Houte, 1994). Bacteriologic studies have shown that MS typically constitutes less than 0.1 percent of the plaque flora present in the mouth of a caries-free child, but often exceeds 30 percent of the cultivable flora in a child with ECC; thus suggesting that presence and quantity of MS are associated with ECC (Berkowitz, 2003; van Houte, 1994; Wan et al., 2001). Some children appear to be more susceptible to bacterial overgrowth of MS than others, thus suggesting a possible genetic component in ECC etiology (Fejerskov, 2004; Werneck, Mira, & Trevilatto, 2010).

Although much is known about the etiology of ECC, some uncertainty regarding unidentified influences on ECC still remains. Moreover, although the aforementioned studies have identified associations between MS and caries, there are many factors involved in this disease, which is perhaps why some studies have not found significant relationships (M. Fontana, et al., 2011). Research regarding the development of ECC has primarily focused on the influence of microbiologic and behavioral factors, but has not sufficiently explored the potential genetic influences at play. Several observational studies have suggested the existence of a genetic influence on caries development, but further research is needed to identify specific genes related to dental caries susceptibility and protection (Werneck et al., 2010).

2.4.2 – pH balance. The MS bacteria harbored in dental plaque feed on components of foods and beverages that enter the oral cavity, known as “fermentable carbohydrates”, especially sugars (including those from fruit) and cooked starch (bread, potatoes, rice, pasta, etc.) (Francisco et al., 2007; Moynihan & Petersen, 2004; Touger-Decker & van Loveren, 2003; Zero, 2004). The term “sugars”, and not “sugar” (which often refers solely to sucrose), is used throughout the body of literature on diet and caries. “Sugars” is used to refer to the totality of monosaccharides and disaccharides in the diet, the most common of which are glucose, fructose, maltose and lactose (Moynihan & Petersen, 2004; Zero, 2004). Upon entering the oral cavity, these carbohydrates are hydrolyzed by salivary amylase, producing a substrate for the actions of oral bacteria (Touger-Decker, 2007).

The oral bacteria ferment these carbohydrate substrates into acids, which in turn lower the pH of plaque and saliva (C. Palmer et al., 2010; Touger-Decker & van Loveren, 2003). This acid production not only disrupts the balance of pH in the oral cavity, but it also promotes the growth and proliferation of MS (Marsh, 1991). The decrease in pH begins the process of tooth decay, demineralization (loss of mineral), which damages the tooth surface creating white spot lesions (decalcifications) on the tooth surface and eventually leads to frank dental cavitation (Francisco et al., 2007; C. Palmer et al., 2010; Touger-Decker & van Loveren, 2003). Enamel demineralization begins when pH levels fall below the critical value of 5.5 (Touger-Decker & van Loveren, 2003). The acids produced by oral bacteria, through the metabolism of fermentable carbohydrates from the diet, cause destruction of the enamel expressed as a white spot, then the protein component of the dentin, which eventually leads to frank cavitation of the tooth (Francisco et al., 2007; C. Palmer et al., 2010; Touger-Decker & van Loveren, 2003). The white spot lesion that is created during demineralization is a precursor to a cavitated lesion; unless the demineralization process is arrested or reversed, the white spot lesion will progress to a cavitated lesion (Fontana & Zero, 2006; Norman Tinanoff & Reisine, 2009).

The oral cavity is able to combat the damaging effects of this imbalance in pH to some degree, through the action of saliva via the remineralization process (Francisco et al., 2007).

Remineralization occurs when minerals (including calcium and phosphates) from saliva are able to diffuse back into the porous surface of the demineralized lesion, and help impede or reverse the damaging process of tooth decay (Kawashita et al., 2011; Touger-Decker & van Loveren, 2003). Repletion of dissolved mineral via remineralization occurs as a result of a rise in plaque and saliva pH levels, above the critical value (Touger-Decker & van Loveren, 2003). The oral cavity undergoes this cycle of demineralization and remineralization multiple times throughout the day (Kawashita et al., 2011). Tooth decay occurs when the process of demineralization outweighs that of remineralization. Whether lesions formed during the demineralization process will progress and worsen, become arrested (remaining unchanged), or become repaired (reversing the damage), depends on the balance between protective and pathological factors influencing the mineralization processes (Fontana & Zero, 2006; Kawashita et al., 2011). If saliva levels are low, there is a high level of bacteria present, or fermentable carbohydrates are consumed often (i.e., frequent snacking), then the pH balance in the mouth will remain below the critical value, resulting in an imbalance between demineralization and remineralization; favoring the former (Francisco et al., 2007).

2.4.3 – Diet. The composition of the diet influences this oral equilibrium process by impacting quantity, pH, and composition of the saliva as well as the pH of dental plaque (Rebecca Harris, Gamboa, Dailey, & Ashcroft, 2012; Touger-Decker & van Loveren, 2003). Frequent (i.e., snacking, grazing) and prolonged (i.e., slow, long-lasting, highly-retentive) consumption of sugars in the diet (fermentable carbohydrates), and actions including putting children to bed with a bottle containing sweetened beverages, and sipping from a bottle or training cup containing sweetened beverages throughout the day are diet-related behaviors that have been highly correlated with ECC (Berkowitz, 2003; Fisher-Owens et al., 2007; Kawashita et al., 2011; Moynihan & Petersen, 2004; Reisine & Litt, 1993; Norman Tinanoff & Reisine, 2009). These behaviors are considered “cariogenic” and thus create conditions that result in prolonged reduction in oral pH level, thereby promoting the demineralization process. ECC risk is greatly impacted by a combination of these infant/child feeding practices and a dietary intake pattern that includes repeated consumption of fermentable carbohydrates (Touger-Decker, 2007). Additional details on the constituents of a cariogenic diet and cariogenic diet-related behaviors are discussed in the subsequent sections below (Section 2.5.1 – Cariogenicity of Foods and Beverages; Section 2.5.2 – Intake Patterns and Oral Exposure Time).

2.4.4 – Oral self-care. In addition to the influence of diet-related factors on oral pH equilibrium, a variety of oral self-care habits are influential as well. Proper oral self-care habits help to minimize accumulation of dental plaque and aid in the promotion of optimal oral pH balance. Tooth brushing after intake of foods and beverages encourages rapid clearance of fermentable carbohydrates from the oral cavity, thereby minimizing exposure to the demineralization processes.

For young children, it may be difficult to independently engage in self-care and thoroughly brush their teeth without assistance from an adult. Insufficient tooth brushing has been indicated as a considerable risk factor for ECC. Research on tooth brushing habits related to ECC has shown that children whose parents assist with tooth brushing beyond 3 years of age have significantly fewer decayed, missing or filled primary teeth (dmft) (Fisher-Owens et al., 2007; Marsh, 1991; Pieper et al., 2012). Use of fluoridated toothpastes and mouthwash is recommended as part of an oral care routine. For children at high risk of ECC, use of fluoridated toothpaste may reduce risk if utilized by 2 years of age (American Academy of Pediatric Dentistry, 2011).

Research has shown that fluoride is most effective in prevention of ECC when low levels are consistently maintained (Gussy et al., 2006; Moynihan & Petersen, 2004). The presence of fluoride in the oral cavity helps to disrupt the demineralization process and fosters the process of remineralization (Touger-Decker & van Loveren, 2003). Fluoride has been shown to reduce the critical pH level in saliva and plaque by 0.5 pH units, thus exerting a protective effect on dental enamel (Touger-Decker & van Loveren, 2003). Although fluoride can help to raise the threshold at which dietary sugars promote demineralization and the progression of the caries process, its protective effect is limited (Zero, 2004). A review study by Burt and Pai (2001) concluded that although the relationship between consumption of sugars and caries development is weakened in the modern age of extensive fluoride exposure, the relationship does still exist and restriction of sugars consumption still plays a role in caries prevention. Engaging in cariogenic diet-related behaviors can overwhelm and outweigh the beneficial effect of fluoride, thus adherence to proper dietary recommendations is still a necessary part of ECC protection.

Additionally, maintenance of adequate quantities of saliva in the mouth is important to aid in oral clearance of foodstuff and promote the remineralization process. Brushing teeth after intake of a meal or snack is preferred, but if unable to do so, chewing sugar-free gum is recommended as a beneficial alternative as it assists in stimulating the flow of saliva, consequently reducing the effect of acids produced by oral bacteria (Francisco et al., 2007).

2.4.5 – Conceptual models. It is clear that ECC is a complex, multifaceted, dieto-bacterial disease which is moderated by a number of internal and external influences. In the

1960's a simple model, with three converging circles, representing the etiology of ECC was proposed by Keyes and Jordan (1963), and only included three main factors: the tooth, the diet, and dental plaque (Touger-Decker & van Loveren, 2003). Since then, additional factors have been widely recognized in the etiology of ECC, including the significant influence of socioeconomic, behavioral and environmental factors, thus models focusing solely on individual-level influences are no longer considered adequate (Fejerskov, 2004; Fisher-Owens et al., 2007; Moynihan & Petersen, 2004).

A multilevel conceptual model has been developed by Fisher-Owens (2007), which describes the complex, dynamic interactions between multiple levels of influence, including the individual, family, and community levels, which drive the development of ECC (Figure 2.2 – Determinants of ECC Conceptual Model). This revised model is derived from the recognition that ECC does not arise as a result of individual-level factors alone, but rather ECC evolves from interactions at multiple levels of influence. Because the individual lives within a family, and that family resides within a larger community, there are several interacting spheres of influence involved in ECC etiology (Fisher-Owens et al., 2007). The Fisher-Owens (2007) model includes 5 key domains that have been identified as determinants of health in previous public health literature: genetic and biological factors, the social environment, the physical environment, health behaviors, and dental and medical care (Fisher-Owens et al., 2007). The model was designed to recognize the complex interplay between multiple factors and incorporates the influence of time on disease progression.

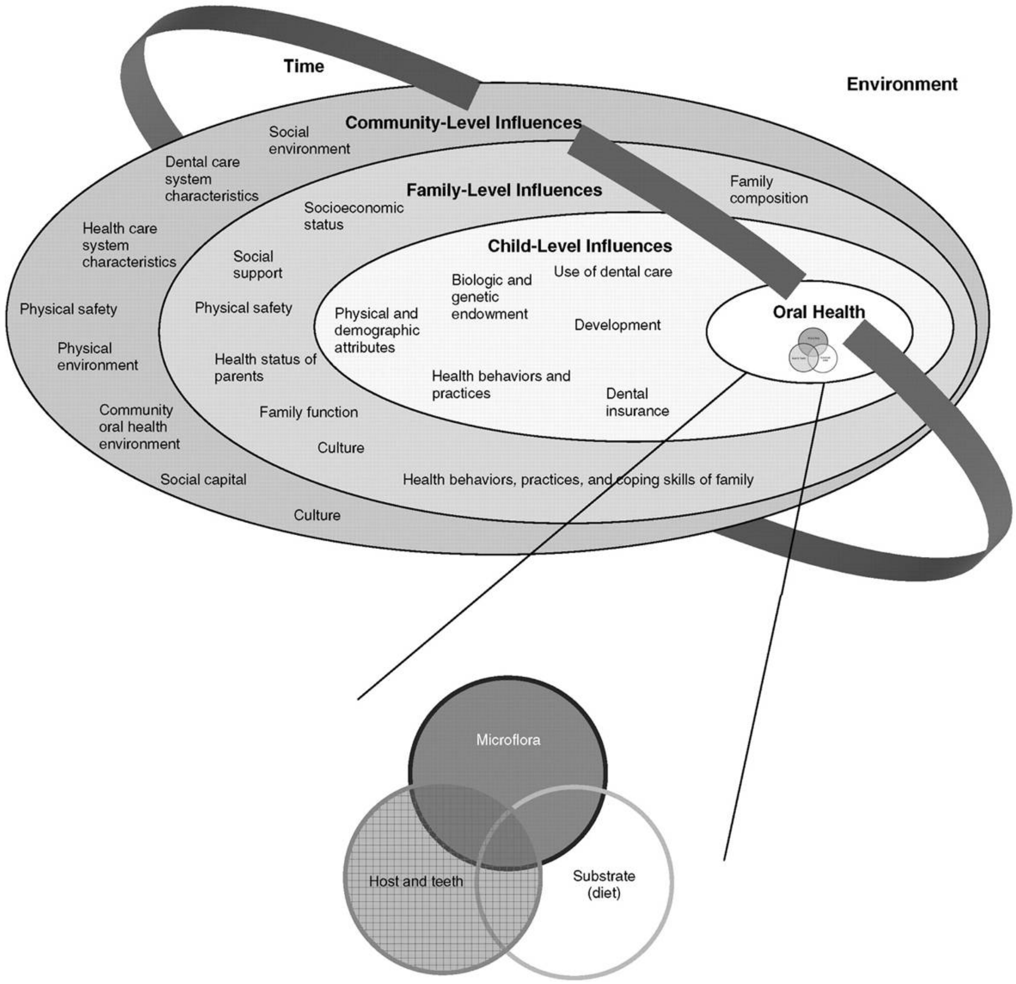

Figure 2.2. Determinants of ECC Conceptual Model. Child, family, and community influences on oral health outcomes of children. Triad adapted from Keyes PH. *Int Dent J*. 1962;12:443–464; concentric oval design adapted from the National Committee on Vital and Health Statistics, Shaping a Health Statistics Vision for the 21st Century. Washington, DC: Department of Health and Human Services Data Council, Centers for Disease Control and Prevention, National Center for Health Statistics; 2002:viii (Fisher-Owens et al., 2007).

The preceding section details the etiology of ECC as a complex, dieto-behavioral, infectious disease. In summary, the etiology of ECC can be explained as consisting of three main steps, each of which contain specific processes that contribute to disease development and progression (Figure 2.3 – Overview of ECC Development and Progression) (Berkowitz, 2003).

The first step can be described as primary infection of the oral cavity by cariogenic bacteria, most often via vertical transmission from primary caregiver to child. The second step that follows is accumulation of bacteria to pathogenic levels, promoted by inadequate exposure to fluoride and increased exposure to a cariogenic diet. The third step can be described as the rapid and destructive process of demineralization, which overwhelms the body's protective remineralization process, and results in lesions, progressing to frank cavitation of the tooth structure if left untreated (Berkowitz, 2003).

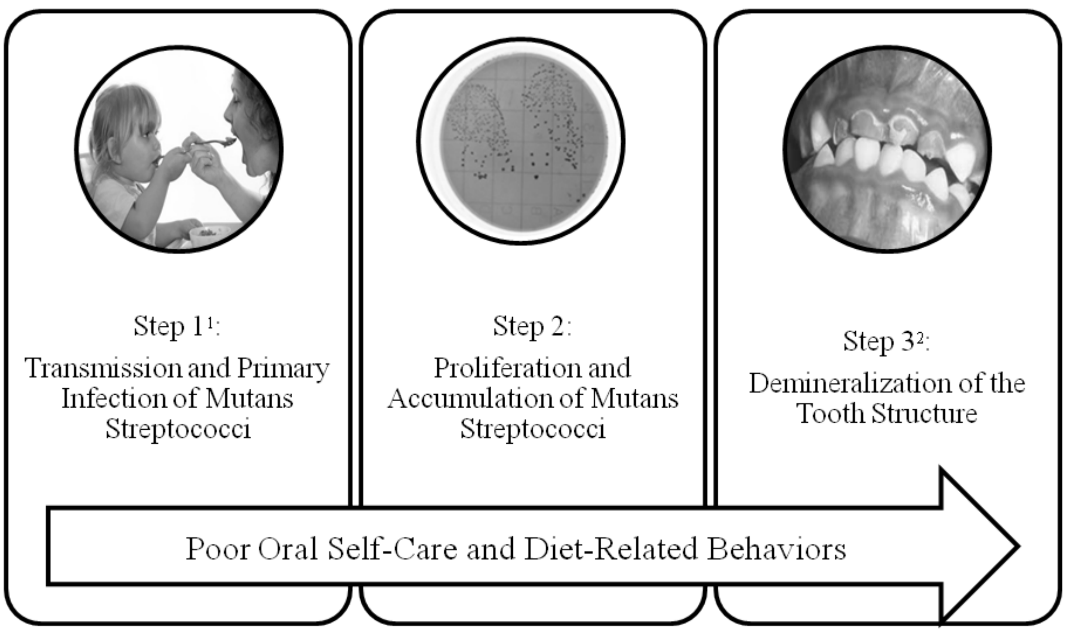

Figure 2.3. Overview of ECC Development and Progression. [1]Step 1 image obtained from MySmileBuddy risk assessment tool (Levine, Wolf, Chinn, & Edelstein, 2012). [2]Step 3 image from Gussy (2006) (Gussy et al., 2006)

2.5 -Diet and Early Childhood Caries

Dietary intake directly influences the tooth decay process and therefore plays an integral role in the development and progression of ECC (*Oral Health in America: A Report of the Surgeon General*, 2000). The primary factors involved in determining diet-related caries risk include the form of food (i.e., liquid, solid, sticky, slow dissolving), the frequency of consumption of sugars and other fermentable carbohydrates, nutrient composition, potential to stimulate saliva, sequence of food intake, and combinations of foods consumed (Mobley, 2003; Sanders, 2004; Touger-Decker & van Loveren, 2003). Examples of these diet-related factors associated with caries risk can be found in the table below (C. Palmer et al., 2010) (Table 2.1 – Dietary Factors That Affect Caries Risk). Additional details regarding each of these factors will be discussed in the subsequent sections following the table.

Table 2.1

Dietary Factors That Affect Caries Risk

Increases Caries Risk	Decreases Caries Risk
Frequent or prolonged between-meal snacking	Having sweets with meals rather than between meals
Frequent or prolonged between-meal sipping on sweetened beverages including juices	Consistent use of fluoride-containing beverages (primarily water)
Use of slowly dissolving hard candies like breath mints and cough drops	Limiting sugared or sugar-free carbonated beverages to meal times only
Frequent between-meal use of cariogenic foods like baked goods and sweets	Using more fresh fruits, vegetables, dairy products, and nuts as between-meal snacks
Use of sticky foods like dried fruits or fruit roll-ups	Using water frequently to clean mouth of food debris
Lack of fluoride in water and other beverages	Limiting between-meal snacking to 2-3 times daily

Note. Table adapted from C. Palmer, et al. (2010)

2.5.1 - Cariogenicity of foods and beverages. Intake of foods and beverages containing fermentable carbohydrates is integral to the initiation and progression of ECC. Cariogenic foods and beverages are defined as those containing fermentable carbohydrates which, when consumed, and in contact with microorganisms in the mouth, result in a decrease in salivary pH to < 5.5, thereby inducing damage to the enamel via demineralization.

The cariogenic potential of food is determined, in large part, by the type of carbohydrate contained in the food, the oral retentiveness of the food, and the presence of protective factors (i.e., calcium, phosphate, fluoride) (Fontana & Zero, 2006; Mobley, 2003; Sanders, 2004). However, the absolute cariogenicity of a food or beverage is difficult to determine because of the impractical and unethical experimental methods that would likely be required for such an analysis. Therefore, the cariogenicity of foods and beverages can be estimated by evaluating acidogenic potential. The ability of a food or beverage to cause a decline in salivary pH reflects the acidogenic potential of the food or beverage (i.e., the ability to induce, and maintain, a shift in the oral pH balance towards acidity). Thus, foods and beverages that are considered highly acidogenic are also considered to be highly cariogenic. Examples of foods and beverages with their corresponding estimated acidogenic potential can be found in Table 2.2 – Acidogenic Potential of Foods (C. A. Palmer, 2001).

Table 2.2

Acidogenic Potential of Foods

Non- to Low-Acidogenic	**Acidogenic (Lesser to Greater)**
Raw vegetables: e.g., broccoli, cauliflower, cucumbers, lettuce, dill pickles, carrots, peppers	Cooked vegetables
Meat, fish, poultry	Fresh fruits (most)
Beans, peas	Sweetened canned or cooked fruits
Nuts, natural peanut butter	Fruit juices, fruit drinks
Milk, cheeses	Sweetened beverages
Flavored yogurts	Non-dairy creamers
Corn chips	Ice cream, sherbet, pudding, gelatin
Peanuts	Potato chips, pretzels, crackers
Popcorn	Marshmallows
Fats, oils, butter, margarine	Bananas, dried fruits, fruit rolls
Non-sugar sweeteners	Slowly-dissolving sugar products: mints, cough drops, candies

Note. Table adapted from C. A. Palmer (2001)

The association between intake of sugars (all mono and disaccharides) and dental caries has long been recognized. Despite numerous limitations associated with the study of this relationship, there is a convincing body of evidence to suggest that both frequency and amount of free sugars intake is related to increased risk of dental caries (Moynihan & Petersen, 2004). A review study by D.T. Zero (2004) noted that population-level comparisons between sugar consumption and caries are limited by inconsistencies in how sugar consumption is reported. There are also inconsistencies in how caries outcomes, namely DMF scores, are measured due to differences in examiner calibration. Furthermore, evaluation of dietary intake data collected at the individual level is also limited due to differences in the types of data collection methods used across the various studies (e.g., food frequency questionnaires, 24-hour recalls, 2-, 3-, and 7-day diaries). Although comparison of findings across the current body of literature is challenged by these limitations, D.T. Zero (2004) does conclude that there is still exceptionally strong evidence to support this relationship between sugars and dental caries.

The term “free sugars” refers to all mono and disaccharides that are added to foods (by a cook, manufacturer, or consumer) plus sugars that are naturally present in honey, fruit juices and syrups (Moynihan & Petersen, 2004). Studies that evaluated caries prevalence rates among populations with low quantities of sugars consumption compared to populations with high levels of sugars consumption, have found that high intake of sugars, especially sucrose, is a primary factor in development and progression of caries (N. Tinanoff & Palmer, 2000). Sucrose is considered the most cariogenic sugar because of its ability to form extracellular glucans, which enable firm bacterial adhesion to teeth and limits diffusion of buffers in the plaque (N. Tinanoff & Palmer, 2000). These water-insoluble glucans enhance accumulation of MS on the surface of teeth and amplify virulence by increasing plaque porosity, resulting in enhanced acid production further decreasing pH levels, and thus promoting demineralization (N. Tinanoff & Palmer, 2000; Zero, 2004; Zero, Vanhoute, & Russo, 1986).

Much of the research on the caries-sugars correlation have primarily focused on intake of sucrose, because sucrose has traditionally been the main source of sugars in the human diet (Moynihan & Petersen, 2004). Several of the classic studies connecting sugar intake with caries development were in relation to the observed decrease in caries rates during World War II; when consumption of sucrose was low due to wartime restrictions (M. Takeuchi, 1961; G. Toverud, 1956). Significant correlations between reduced availability of sugar and depressed caries rates were established in these population-level studies. Since these classic studies, dietary intake patterns have changed in modern industrialized countries and now include a variety of sugars and other carbohydrates; such as glucose, lactose, fructose, glucose syrups, high fructose corn syrup and other synthetic oligosaccharides; and highly processed starches that are fermentable in the oral cavity (Moynihan & Petersen, 2004). Starches have become increasingly processed and consumption of these highly processed starches, many of which are also high in free sugars (e.g. corn snacks, sweetened cereals, and cakes), has increased in some countries (Moynihan & Petersen, 2004).

Fermentable carbohydrates in the form of starches are generally considered less cariogenic than simple sugars (e.g., sucrose, glucose and fructose) (Zero et al., 1986). Starches that are consumed raw (e.g., fruits and vegetables) are considered of low cariogenicity because they do not appear to cause a significant decrease in pH which leads to subsequent demineralization of the enamel (Gibbons, 1995; Moynihan & Petersen, 2004). However, starches are commonly consumed in cooked form, and both human and animal studies suggest that consumption of cooked starch does possess cariogenic potential. Cooked starches possess approximately one-third to one-half the cariogenic potential of sucrose (Moynihan & Petersen, 2004). The addition of sugar increases the cariogenicity of cooked starchy foods, and may increase it to similar levels as sucrose (Gibbons, 1995). Food rich in starch that do not contain added sugars have been shown to play only a small role in caries development (Rebecca Harris et al., 2012; Moynihan & Petersen, 2004). Many of the common staple foods (e.g., whole grain foods) that are less refined than processed starches contain properties that protect against the demineralization process (Gibbons, 1995). For example, whole grain foods require more mastication, thereby stimulating secretion of saliva and increasing pH buffering capacity, and many unrefined plant foods contain phosphates, which may convey a protective effect against demineralization as well (Moynihan & Petersen, 2004). However, intake of sweetened starches, like sugar-sweetened cereals, has been shown to exert high cariogenic potential (Gibbons, 1995; Nainar & Mohummed, 2004a). Moreover, despite the lower innate cariogenicity of starches as compared to simple sugars, starches that are retained in the mouth for prolonged periods of time may present a caries risk comparable to that of high sucrose foods because of decreased oral clearance time (Mariri et al., 2003; Zero et al., 1986).

Unlike sugars found in solid foods, including starches (e.g., crackers, cookies) sugars in liquid form (e.g., juices, soft drinks) are generally cleared from the oral cavity rapidly, unless consumed frequently or over a prolonged period of time. Sugars in liquid form, themselves, have thus been shown to be less cariogenic than sugars in solid form; however excessive consumption of sugar-containing beverages remains a major risk factor for caries because of increased oral exposure time (Heller, Burt, & Eklund, 2001; Ismail, Burt, & Eklund, 1984). Increased intake of sugar-containing beverages among children has been implicated as a risk factor for ECC (Marshall, 2003; N. Tinanoff & Palmer, 2000). Several cohort studies of children 1 to 5 years of age found that daily intake of sugar-containing beverages, especially overnight, and total daily sugar intake were independent risk factors in ECC development (Grindefjord, Dahllof, Nilsson,

& Modeer, 1996; Karjalainen, Soderling, Sewon, Lapinleimu, & Simell, 2001; Rodrigues & Sheiham, 2000; Wendt, Hallonsten, Koch, & Birkhed, 1996).

In addition to physical form of foods and the type of sugars present, other factors are important in determining cariogenic potential. Several elements present in foods have been found to exert a beneficial influence on cariogenic potential, and are able to act as protective factors against ECC (Fontana & Zero, 2006) (Touger-Decker & van Loveren, 2003). For example, sugars that are naturally incorporated into the cellular structure of foods (intrinsic sugars), like lactose in milk and sugars in fruit, have not been shown to directly exert adverse effects on oral health (Rebecca Harris et al., 2012).

Milk and cheese contain the sugar lactose, but also contain calcium, phosphorus, and casein, all of which may inhibit the dental caries process (Moynihan & Petersen, 2004). Intake of foods that contain high levels of calcium, phosphate, and protein has been shown to favor the remineralization process (Touger-Decker & van Loveren, 2003). Aged cheese, for example, has been shown to exert a protective influence against caries development, by stimulating salivary flow and raising the calcium, phosphorous, and protein content of dental plaque (Moynihan & Petersen, 2004; N. Tinanoff & Palmer, 2000). Additionally, intake of milk, and other dairy-based products, has been shown to provide some protection due to its mineral content (Nainar & Mohummed, 2004a). As a result of these properties, studies have shown that consumption of cow's milk products does not result in the same decrease in oral pH as intake of free sugars (Moynihan & Petersen, 2004). Therefore, intake of milk, itself, is not considered cariogenic because of the protective properties it possesses; however milk does hold the potential to become cariogenic based on intake pattern (i.e., if consumed over prolonged periods of time).

Much like milk, fruits naturally contain sugar but are not considered highly cariogenic; though they may hold the potential to be cariogenic depending on intake form and pattern (N. Tinanoff & Palmer, 2000). Generally, fresh fruits consumed as part of a mixed diet are considered of low cariogenicity (Moynihan & Petersen, 2004). Unlike fresh fruits, which are high in fiber, fruit juices are considered cariogenic (N. Tinanoff & Palmer, 2000) Fiber is believed to exert a protective effect on teeth, largely because consumption of fibrous foods elicits increased salivary flow which promotes remineralization and aids in oral clearance of foodstuff (Moynihan & Petersen, 2004). Unfortunately, as a result of the relatively low cost of fruit juices, high acceptability by children and belief among many parents that juices are nutritious, intake of this cariogenic beverage over fresh fruit is high among children (N. Tinanoff & Palmer, 2000). Similarly to fruit juices, dried fruit may also be more cariogenic than fresh fruit because the cellular structure is broken down during the drying process, thereby releasing free sugars (Moynihan & Petersen, 2004). Dried fruit also tends to remain in the oral cavity for longer periods of time, thereby increasing oral exposure to sugars.

2.5.2 - Intake patterns, oral exposure time, and dental caries. In regard to ECC risk and overall cariogenicity of the diet, it is the amount of time that the oral cavity is exposed to fermentable carbohydrates, rather than total amount consumed, that is the most critical factor to consider (R Harris et al., 2004; Heller et al., 2001; C. Palmer et al., 2010). Thus, it may not be the total amount of sugars consumed, but how they are eaten (consistency and frequency), that most determines cariogenicity (Featherstone, 2000; Touger-Decker & van Loveren, 2003). Since overall cariogenicity of the diet is most highly associated with frequency of exposure, consumption patterns are of paramount importance in ECC risk (Edmondson, 1990; Krasse, 2001; Marshall et al., 2005).

The landmark study which first closely evaluated the relationship between dietary sugars and caries was the classic Vipeholm Study (Gustafsson et al., 1954). The Vipeholm study evaluated the effects of frequency, timing, and consistency (oral retentiveness) of sugar consumption on dental caries rates (Gustafsson et al., 1954; Krasse, 2001; N. Tinanoff & Palmer, 2000). The Vipeholm Study was a tightly controlled intervention conducted among institutionalized individuals, thus allowing the researchers to exert complete control over the dietary intake of participants. The Vipeholm Study was the first of its kind to show that the addition of sugar to the diet not only caused increased caries activity, but notably, the degree of caries was highly dependent on the consistency and intake pattern of the sugar consumed (Gustafsson et al., 1954; Krasse, 2001; Papas, Joshi, Palmer, Giunta, & Dwyer, 1995; N. Tinanoff & Palmer, 2000). The Vipeholm study revealed that sugars consumption increased caries experience most, when consumed between meals and in a highly retentive form (e.g., sticky toffee) (Gustafsson et al., 1954). The findings from this classic study are still endorsed and supported by research today. The Vipeholm study concluded that caries activity is greatest when sugar is consumed in the form of a sticky, highly retentive food; caries activity is increased when sugar is consumed as snacks, between meals; intake of sugars with meals slightly increased caries activity; and caries activity declines when sugar is withdrawn from the diet (Gustafsson et al., 1954; Krasse, 2001; Papas, Joshi, Palmer, et al., 1995; N. Tinanoff & Palmer, 2000).

As noted, sugars have been significantly associated with dental caries, but mostly when consumed in highly retentive forms and between meals (Gustafsson et al., 1954; Krasse, 2001; N. Tinanoff & Palmer, 2000). Therefore, the form of fermentable carbohydrate (i.e., liquid, solid, sticky) directly influences the duration of oral exposure time and retention of sugars on the teeth (Touger-Decker & van Loveren, 2003). Intake of foods that are retained in the mouth for extended amounts of time (e.g., hard candy, lollipops, cough drops) causes a slow release of sugars into the oral cavity, and results in periods of prolonged acid production by MS in plaque, thereby promoting demineralization (N. Tinanoff & Palmer, 2000; Touger-Decker & van Loveren, 2003). Likewise, foods that are highly retentive, that adhere to the surfaces of teeth because they are sticky (e.g., gummy candy, taffy, caramels) or starchy (e.g., crackers, cookies, pretzels), result in periods of prolonged demineralization (Mariri et al., 2003; Zero et al., 1986).

The extremely high prevalence and severity of ECC in preschool children has been shown to be significantly related to frequency of sugars consumption (Norman Tinanoff & Reisine, 2009). This relationship is due to the fact that high frequency of sugars in the diet enables repetitive production of acid by cariogenic MS bacteria, thereby supporting demineralization (Norman Tinanoff & Reisine, 2009). Caries risk has been shown to increase in direct relation to the total number of eating/drinking occasions per day (C. Palmer et al., 2010). The total number of eating occasions throughout the day has been shown to be positively associated with S-ECC (Mariri et al., 2003). Furthermore, frequent intake of sugars from nonmilk sources (e.g., soft drinks, cake, juices, honey, table sugar, confectionery items), beyond four times a day, has been shown to result in increased risk of dental caries (Rebecca Harris et al., 2012; Hooley, Skouteris, Boganin, Satur, & Kilpatrick, 2012; Moynihan & Petersen, 2004). Research has shown that children with S-ECC consume more total foods/beverages a day, and eat/drink more frequently than caries-free children (C.A. Palmer, et al., 2010).

Additionally, feeding practices that promote high intake of between-meal foods and beverages has also been indicated in ECC risk (Gustafsson et al., 1954; Krasse, 2001; C. Palmer, 2010; Papas, Joshi, Palmer, et al., 1995). Intake of foods/beverages on a regular, frequent, and continuous basis is associated with both ECC and obesity (Bruce A Dye et al., 2007; Mobley et al., 2009). Evidence suggests that snacking on cariogenic foods and beverages throughout the day has been implicated in the development of ECC (Papas, Joshi, Palmer, et al., 1995; Weinstein, 1998). However, a study on diet and caries-associated bacteria found that food/beverage frequency was independently associated with caries, regardless of cariogenic potential of the item (C.A. Palmer, et al., 2010). Another study evaluating consumption patterns of children with and without S-ECC found that children with S-ECC had more between-meal beverages and more solid, retentive foods than caries-free children (C. Palmer, 2010). Another study by Weiss and Trithart (as cited by (Papas, Joshi, Belanger, et al., 1995)) found that a linear relationship exists between number of snacks consumed throughout the day and incidence of caries. Conversely, intake of foods in combination may help reduce cariogenic potential of the meal. For example, intake of presweetened cereals have been found to be cariogenic, however when consumed with milk, the cariogenicity is decreased (Nainar & Mohummed, 2004a). This decrease in cariogenicity is likely a result of reduced duration of oral exposure, due to liquid washing over the oral cavity, combined with the caries-protective effect of milk consumption (Nainar & Mohummed, 2004a; N. Tinanoff & Palmer, 2000).

Both quantity and frequency of sweetened beverage intake have been associated with ECC (Mariri et al., 2003). Although sweetened beverages are considered cariogenic because of their content of simple sugars, it is the manner in which beverages are consumed (i.e., snack vs. meal, prolonged sipping vs. quick drinking, daytime vs. nocturnal feedings) that most strongly influences cariogenicity (Marshall et al., 2003) (American Academy of Pediatric Dentistry, 2011; Hague, 2011; Mobley, 2003; N. Tinanoff & Palmer, 2000). These liquid forms of fermentable carbohydrate typically pass through the oral cavity quickly, with limited contact time or adherence to tooth surfaces (Touger-Decker & van Loveren, 2003). However, their cariogenic potential can be greatly enhanced, depending on the frequency and pattern of intake. For example, sweetened beverages that are consumed during meals are not highly cariogenic, whereas those that are held in the mouth for prolonged periods of time, or that are slowly sipped over an extended period of time also greatly increase risk of ECC (American Academy of Pediatric Dentistry, 2011; Hague, 2011; Hooley et al., 2012; Mobley, 2003; C. Palmer, 2010; Touger-Decker & van Loveren, 2003). For example, research has shown that sipping a soft drink over a five-hour period can actually be more dangerous to caries risk than drinking three soft drinks during one meal (Fontana & Zero, 2006). Therefore, prolonged use of bottles or no-spill training “sippy” cups (filled with anything other than water) is discouraged (American Academy of Pediatric Dentistry, 2011/2012).

As a result of prolonged oral exposure time, children who are put to sleep with a bottle or no-spill training cup (with a sugar-containing beverage, including milk), and those who are given a bedtime snack or sweetened beverage prior to sleep, have been found to be at elevated risk for ECC (Hooley et al., 2012; Kawashita et al., 2011; Pieper et al., 2012). Nocturnal feeding practices, which result in slow oral clearance of fermentable carbohydrate because they occur during a time when salivary flow rate is already reduced (due to sleep), greatly increase the frequency and duration of enamel demineralization (Kawashita et al., 2011). In addition to nighttime bottle use, evidence from case studies has suggested that prolonged ad libitum and nocturnal breastfeeding have been linked to ECC; however further study is needed to determine whether the risk can be primarily attributed to these breastfeeding practices or other child-rearing and dietary practices (Moynihan & Petersen, 2004; N. Tinanoff & Palmer, 2000). An evaluation of NHANES data for over 1500 children 2-5 years of age, conducted by Iida, et al. (2006), explored the relationship between breastfeeding and ECC. The researchers determined that there was no evidence to support the notion that either breastfeeding, or duration of breastfeeding, are independent risk factors for ECC. Interestingly, this study found that 60 percent of breastfed children actually had lower rates of ECC and S-ECC. Ad libitum breastfeeding was hypothesized to be associated with caries because of the inherent frequency of oral exposure to the high sugar content of breast milk, but this was not found to be a significant risk for ECC.

There are clearly numerous diet-related factors involved in the initiation and progression of ECC. The frequency of eating/drinking fermentable carbohydrate-containing foods/beverage items, the characteristics of the items consumed (i.e., consistency, form, oral retentiveness), the intake patterns (i.e., between-meal vs. meal, prolonged vs. rapid) are all important factors involved in the diet-ECC relationship (C.A. Palmer, et al., 2010; Gustafsson et al., 1954; Heller et al., 2001; Krasse, 2001; Mobley, 2003; Sanders, 2004; Touger-Decker & van Loveren, 2003).

The table below presents a summary of several key epidemiologic studies that evaluated the relationship between diet and dental caries (Table 2.3 – Diet and Dental Caries Epidemiologic Studies). Overall, evidence suggests the fewer between-meal snacks and sweetened beverages consumed, and the shorter the oral exposure time of foods/beverages consumed, the lower the diet-related risk for ECC (Heller et al., 2001; C. Palmer et al., 2010).

2.6 - Early Childhood Caries Treatment and Interventions

As previously detailed, ECC is a complex, multifactorial disease. As such, it can be classified along with diseases, such as cancer, cardiovascular disease, and diabetes, that all arise out of a series of complex interactions between genetic, environmental and behavioral risk factors (Fejerskov, 2004). As a result of its complex nature, ECC has been a decidedly difficulty disease to treat. Traditional treatment methods have not proven successful, and research has shown that previous caries experience is a strong predictor of future caries; therefore new approaches to disease management and prevention must be explored (Helm & Helm, 1990; Tinanoff & Reisine, 2009).

Table 2.3

Diet and Dental Caries Epidemiologic Studies

Study	Design/Measures	Key Outcomes
Palmer, 2010	-Prospective case series -*N* = 111; Children -Open-ended 24-hour dietary recall and validated beverage survey -To compare dietary intake of S-ECC children with caries-free children	-S-ECC participants had higher intake of cariogenic liquids, solid/retentive foods and higher estimated food or beverage cariogenicity -S-ECC participants with lesion recurrence ate fewer caries-protective foods compared with those without new lesions -Participants who tested positive for MS had high estimated cariogenicity scores
Marshall, 2005	-Cohort Study -*N* = 634; Children - 3 day food diary -To investigate associations between dietary intake and caries risk -Variables included meal/snack/daily total exposures -Food/beverage exposures categorized by carbohydrate content	Increased caries significantly associated with: -Higher snack and daily total eating events -Higher exposure to 100% juice at snacks -Higher exposure to soda at meals -Higher exposures to sugars at snacks Decreased caries risk significantly associated with: -Higher exposure to food sugars and starches at meals
Mariri, 2003	-Case-control cohort study -*N* = 78; Children -3 day food and beverage diaries -To compare dietary intake of S-ECC children with caries-free children	S-ECC significantly associated with: -Higher regular pop/other sugared beverage intake -Higher frequency of starch foods -Higher frequency of eating occasions
Gustafsson, 1954	-Cohort study -*N* = 436; Children -Inpatients with experimentally controlled diet	-Positive correlation between consumption of sugar (at/between meals) and caries -Sugar consumption between meals has larger effect on increasing caries

Study	Design/Measures	Key Outcomes
	provided -Variables included type of sugar ingested (sticky or non-sticky form) and frequency of sugar intake (at or between meals) -To determine the relationship between diet, frequency of sugar intake and dental caries	than consumption during meals; even if sugar is taken up to four times a day at meals -Caries activity is affected by the addition and withdrawal of sugar-rich foods; caries increases upon addition and decreases upon withdrawal
Heller, 2001	-Cross-Sectional Study -N = 30,818; Children and Adults -FFQ and 24-hour recall -Dietary and dental examination data from the 1988-94 NHANES III -To investigate associations between sugared soda consumption and caries (DMFS/dfs)	High DMFS significantly associated with: -Soda consumption in participants over age 25 years; this may be due to cumulative effects of long-term consumption of sugared soda High DMFS/dfs not significantly associated with: -Soda consumption in adults < 25 or children <12; this may be related to increased use of fluorides since 1960's
Ismail, 1984	-Retrospective Cross-Sectional Study -N = 3,194; Children and Adults -FFQ and 24-hour recall -Dietary and dental examination data from 1971-74 NHANES I -To assess cariogenicity of soft drinks	High DMFT significantly associated with: -Frequencies of at/between-meal consumption of soft drinks -Associations remained after accounting for reported concurrent consumption of other sugary foods -Findings suggest that sugary solutions may not be less cariogenic than sticky snacks
Papas, 1995	- Cross-sectional study -*N* = 275; Adults 44-64 years of age -Modified Block FFQ -Variables included consumption per week of sugars, starch, cheese, fruits and fruit juices, non-cariogenic foods, and dairy products -To assess which nutritional variables differentiate adults with root caries and caries-free adults	-Increased intake of sugar was associated with being in the root caries group -Increased intake of cheese was negatively associated with root caries; cheese seemed to have a protective effect after sugar intake was controlled for -An increase of two exposures of sugar per day corresponded with an odds ratio of 1.26, and an increase to five sugar exposures per day results in an odds ratio of 1.79

2.6.1 – Traditional treatment methods. The field of dentistry arose as a surgical specialty with little focus on medical management of diseases, which encouraged the establishment of a "one-size-fits-all" approach to care (B. L. Edelstein, 2008). In line with this approach, ECC has been historically viewed as a progressive disease that will, over time, lead to the destruction of the tooth unless surgical or restorative intervention is applied (American Academy of Pediatric Dentistry, 2011/2012). These intervention techniques for ECC often require expensive restorative treatments and extraction of decayed teeth (Kawashita et al., 2011; Norman Tinanoff & Reisine, 2009). ECC has classically been treated with the so-called, "drill and fill" approach to dental management. This conventional treatment approach is not a long-term solution, as it does not address the underlying cause of the disease; it is simply a temporary solution to the immediate problem of frank cavitation and often pain. Conventional "drill and fill" approaches are usually restricted to the removal or restoration of carious teeth and do not impact oral bacteria (MS) levels or feeding behaviors (Berkowitz, 2003). The classic approach typically involves removal of decayed portions of the tooth with the use of a drill, with subsequent filling of the resultant void with a restoration compound. Common materials used to fill the tooth include composites (white fillings), amalgam (silver fillings), and stainless steel crowns (caps) (B. Edelstein, 2005). These restorative treatments to repair the tooth structure do not stop or reverse the caries disease process, are known to have a finite life span, and are, themselves, susceptible to disease (Alfano et al., 2001; American Academy of Pediatric Dentistry, 2011/2012; Kawashita et al., 2011).

It appears that there has been a general uncritical acceptance of providing traditional restorative care in this manner, which involves surgical removal of carious teeth, and frequently occurs within a hospital setting (Berkowitz, 2003; Weinstein, 1998). ECC is a disease of early childhood, thus those affected are quite young, and unable to appropriately cope with the necessary procedures to treat damage to their teeth (Norman Tinanoff & Reisine, 2009). As a result, many children treated via conventional methods lack “cooperative ability” and therefore require the use of deep sedation or general anesthesia (Berkowitz, 2003; Norman Tinanoff & Reisine, 2009; Yoon et al., 2012). A study of parents’ experience with ECC treatment under general anesthesia for their preschool children found that this type of dental care is well-received by parents, despite concerns about anesthesia-related morbidity and postoperative pain (Amin et al., 2006). Restorative treatment for S-ECC is quite often treated in this manner, and is the leading cause of childhood hospitalization for treatment under general anesthesia (Sheller et al., 1997). Sheehy (1994) as cited in Weinstein (1998) and Berkowitz (2003) reported that approximately two-thirds of children surgically treated for caries were not responsive to follow-up care, with over half of them who presented for a 6 month follow-up exhibiting new caries that extended into the dentin level of the tooth (Berkowitz, 2003; Weinstein, 1998). Surgical treatment for ECC has resulted in unacceptable clinical outcomes and high relapse rates of approximately 40% within the first year (Berkowitz, 2003; Kawashita et al., 2011). As a result, a significant number of children treated in this costly, and extreme manner, require additional dental treatments after treatment under general anesthesia thereby increasing costs and morbidities associated with caries (Weinstein, 1998) (Amin et al., 2006; Berkowitz, 2003).

Since the disease process is not eradicated by these traditional treatment methods, the ECC continues to affect the child long after these costly treatments are employed. These traditional methods of ECC treatment are therefore not considered sustainable for states, families, or taxpayers as they inflict an incredible financial burden on third-party payers (e.g., Medicaid and the State Child Health Insurance Program) and parents, many of whom are among the least likely to afford it (Berg & Stapleton, 2012; Berkowitz, 2003). Despite the fact that traditional restorative care for ECC is relatively convenient for the parent and the dental professional, it eliminates the child's pain associated with tooth decay, and has economic incentives for clinicians, it is highly problematic, not just in terms of increased costs and need for future restorations, but also because with this treatment, what the clinician does is more important than the preventive message provided (Weinstein, 1998). Traditional restorative treatments reinforce the false belief that caries is a static, isolated problem that is to be repaired by a clinician, rather than promoting the fact that caries can be prevented with behavioral lifestyle modifications (Weinstein, 1998).

Conventional treatments for ECC are similar to those applied in other chronic diseases; they are focused on cures (though often temporary) rather than disease prevention or chronic disease management (Centers for Disease Control and Prevention, 2009). If we are to successfully reduce prevalence and severity rates of ECC, we must focus on creating coordinated, strategic prevention programs to promote healthy behaviors, expand early detection and diagnosis of disease, and eliminate disparities among disadvantaged populations (Centers for Disease Control and Prevention, 2009). In order to incorporate these strategies in the fight against ECC, we must focus on disease prevention.

2.6.2 – Disease prevention. Chronic diseases, such as ECC, are often highly preventable, but they require numerous inputs throughout the lifespan. Since conventional treatment methods do not address the underlying causes of ECC, many countries have shifted toward a preventative and preservative approach to ECC management (Kawashita et al., 2011). The importance of chronic disease prevention is evident in the United States as well, with approximately two-thirds of adults in agreement that preventive care must be emphasized if chronic disease rates are to be reduced (Centers for Disease Control and Prevention, 2009). The major elements of an effective ECC prevention schema include: diet counseling; fluoride therapy; use of dental sealants; and control of cariogenic bacteria, designed to maintain an equilibrium in the dynamic demineralization-remineralization process (Kawashita et al., 2011).

Primary disease prevention. According to the CDC, prevention encompasses health promotion activities that encourage healthy living and limit the initial onset of chronic diseases (Centers for Disease Control and Prevention, 2009). This form of prevention can be referred to as primary prevention, as it helps to prevent disease occurrence by avoiding disease determinants (B. Edelstein, 2005). In regard to ECC, primary prevention should involve efforts to limit bacterial transmission and proliferation to reduce risk of demineralization. This method of prevention should occur prior to colonization of oral bacteria and should emphasize the importance of careful control of caries-promoting activities (B. Edelstein, 2005).

Early interventions to instill healthy behaviors and practices during youth have been shown to be significantly more cost-effective than efforts applied after unhealthy behaviors are entrenched (Centers for Disease Control and Prevention, 2009). An evaluation of effective intervention models found that those targeting the youngest children take approximately 2 to 4 years longer to reach the entire preschool population, but ultimately will exert a greater influence on reducing ECC rates (Hirsch, Edelstein, Frosh, & Anselmo, 2012). Early interventions that target ECC reduction should begin shortly after the eruption of the first tooth, and can be effective in controlling and reducing future ECC risk (Minah et al., 2008). A study evaluating a risk-based ECC prevention program at an urban pediatric primary care clinic found that administration of prevention measures reduced caries experience in this high risk, low socioeconomic status, population of infants and toddlers (Minah et al., 2008). Thus, primary prevention in efforts to reduce caries rates be emphasized and begin early in the life cycle, including prior to birth via prenatal education programs and during the first few years of life (N. Tinanoff & Palmer, 2000).

Anticipatory guidance is an approach to child care that has been utilized in ECC primary prevention efforts (B. Edelstein, 2005; Fitzsimons, Dwyer, Palmer, & Boyd, 1998). Anticipatory guidance promotes positive health behaviors by guiding parents to take action in anticipation of conditions that could be harmful (B. Edelstein, 2005; Fitzsimons et al., 1998). The concept of a "dental home" has been promoted by the American Academy of Pediatric Dentistry (AAPD) as a means of providing primary prevention of ECC (American Academy of Pediatric Dentistry, 2011). A dental home is used to describe the ongoing relationship between dentist and patient, and provision of oral health in a comprehensive, continuously accessible, coordinated, and family-centered way (Dentistry, 2006/2010). Establishment of a dental home is recommended by the AAPD within 6 months of the eruption of the first tooth and no later than 12 months of age to conduct a caries risk assessment provide referral to additional health care providers as needed, and provide anticipatory guidance and education to parents (American Academy of Pediatric Dentistry, 2011). Since ECC is a disease established early in life, application of the dental home model provides timely access to educational and behavioral interventions.

There is evidence to suggest that the first five years of life are when eating behaviors form the foundation for future eating patterns (Savage, Fisher, & Birch, 2007). Thus programs targeting early intervention and education of parents may be most successful in promoting positive behaviors. Several studies have evaluated the impact of early parental education on lowering children's risk of ECC. One study found that diet and oral hygiene counseling combined with fluoride supplements helped reduce caries experience by 65 percent among children 4 years of age (Holst & Kohler, 1975). A second study which implemented a similar prevention program resulted in a 42 percent reduction in caries prevalence after 4 years (Holm, Blomquist, Crossner, Grahnén, & Samuelson, 1975). A third study provided dietary counseling and the development of ECC to parents during their child's first year of life (Feldens, Justo Giugliani, Duncan, Drachler, & Vitolo, 2010). Parents in this study were provided with advice about bottle usage and intake of added sugar in the diet (including juices, soft drinks, and snacks), and found that counseling effectively reduced incidence of caries by 22 percent (RR 0.78; 95% CI 0.65-0.93) (Feldens et al., 2010). Additionally, a study which employed the use of community health workers (CHWs) found that individual counseling during well-child visits at a community health clinic resulted in fewer use of bottles during daytime and sleep-time and ultimately resulted in lower prevalence of caries (R. Harrison, 2003). A similar intervention technique was employed in a study that evaluated efforts by dentists and other dental staff members to effectively change patients' diets (Rebecca Harris et al., 2012). This study utilized one-to-one dietary interventions, focused on general health promotion, conducted within a dental care setting to assess impact on diet-related behaviors (Rebecca Harris et al., 2012). The study determined that there is evidence to suggest that individualized dietary interventions, promoting general health (as opposed to oral health) are effective in changing dietary behaviors (Rebecca

Harris et al., 2012). The researchers suggested that there is a paucity of data on effectiveness of such interventions on reducing caries risk, but evidence from this study is promising (Rebecca Harris et al., 2012). Programs, such as these, that provide treatment for ECC should aim to reduce child risk by changing parenting behaviors through counseling and behavior change management (Weinstein, 1998). Research confirms that education alone is not sufficient to initiate adoption of appropriate ECC prevention behaviors (Reisine & Litt, 1993). In order to achieve successful ECC prevention, interventions must incorporate behavioral modification techniques and focus on multiple strategies of oral health promotion simultaneously (Reisine & Litt, 1993).

Motivational interviewing is a counseling style that has been shown to be effective in eliciting health-related behavior change. Motivational interviewing focuses on working with individuals to help them identify discrepancies between their behaviors and beliefs, and then exploring such discrepancies to promote positive behavior change. This technique utilizes reflective listening and a tailored, individualized approach to behavior change. Motivational interviewing has been utilized in a number of health promotion interventions, but has only recently been employed in the prevention of ECC. A study promoting positive changes in ECC-related risk behaviors in mothers enrolled in the Women, Infants and Children (WIC) program applied motivational interviewing techniques (Freudenthal & Bowen, 2010). This study found that motivational interviewing promoted statistically significant positive behavioral changes, specifically in regard to cariogenic feeding and oral health practices (such as sharing utensils ($p = 0.035$) and tooth brushing ($p = 0.001$)) (Freudenthal & Bowen, 2010). This study suggests that interventions targeting modification of cariogenic behaviors via motivational interviewing may be successful in reducing rates of ECC (Freudenthal & Bowen, 2010).

Effective behavior modification programs must also be tailored to the unique needs of their target audiences. A study of parents and staff from an Early Head Start (EHS) program, found that parents had varying levels of oral health understanding (Mofidi et al., 2009). Many of the parents did in fact recognize the importance of early oral care, but some did not. Some of the parents held the incorrect belief that primary teeth (baby teeth) are unimportant because they are deciduous and the focus should be on caring for permanent teeth (Mofidi et al., 2009). In a population such as this, it would be most appropriate to initially emphasize the importance of early oral health and its implications for lifelong oral and systemic health prior to providing education on oral care techniques. Therefore, effective program design should address concerns and knowledge gaps specific to the target population, and should be culturally and linguistically appropriate (Mofidi et al., 2009).

Beyond educationally-focused prevention programs, efforts to reduce ECC have also involved use of oral prophylaxis treatments. Encouragement of tooth brushing with fluoridated toothpaste, application of fluoride varnishes, and use of xylitol-containing foods and gums have been shown to be effective prophylaxis treatments in reducing caries rates. In a study of caregiver treatment acceptability and preferences among primary caregivers of Hispanic children, researchers found that caregivers found these prophylaxis treatments highly acceptable for their young children (Adams et al., 2009). Although this study found that all treatments were viewed positively by caregivers, it found that caregivers felt tooth brushing with fluoridated toothpaste and application of fluoride varnish were more acceptable than xylitol in foods (p <

0.05) (Adams et al., 2009). As a result, researchers concluded that caregivers are interested in both receiving professional oral care as well as developing healthy oral self-care practices at home (Adams et al., 2009). Despite the proven benefits of fluoride on caries risk, it is not a sufficient solution on its own. Fluoride use has its limits, and without properly addressing diet-related behaviors, its impact is often overshadowed by caries-promoting dietary behaviors (Zero, 2004). Thus, interventions should promote clinical prophylaxis measures as well as behavior change.

Secondary disease prevention. In addition to primary prevention methods, effective ECC mitigation efforts should also include methods of secondary prevention. Secondary prevention can be viewed as disease management and control efforts, which occur after the onset of disease progression. Research has shown that previous caries experience is a strong predictor of future caries (Helm & Helm, 1990; Tinanoff & Reisine, 2009). Because the disease process of ECC is not arrested by conventional treatments, contemporary secondary prevention methods should include early detection of non-cavitated lesions (precursors for frank cavitations), and should utilize active surveillance of disease and apply preventive measures to arrest or reverse present tooth decay damage (American Academy of Pediatric Dentistry, 2011/2012). Early intervention in the ECC disease process is preferred because the caries process can be arrested by timely and effective management, minimizing the need for restorative care (Yoon et al., 2012). Intervention models that include targeting children at highest risk for ECC, have been shown to provide the greatest return on investment, and when interventions target ECC at multiple stages of the disease process, they wield a significant potential for disease reduction (Hirsch et al., 2012).

Even after the onset of the ECC disease process, educational interventions and application of fluoride treatments have been proven effective, similarly to their use primary prevention efforts. A study evaluating the use of fluoride and xylitol on caries rates, followed children 11 to 12 years of age (n = 497) who had at least one active carious lesion for a period of 3.4 years (Shenkin, 2011). The children in the experimental arm of this study were provided with toothbrushes, fluoride toothpaste, and xylitol lozenges, and were given nutrition and oral hygiene counseling (Shenkin, 2011). This study found that the experimental group had more DMFS averted than the control group (Shenkin, 2011). This study showed that a secondary prevention program providing counseling in addition to applied oral care products effectively reduced caries recurrence rates (Shenkin, 2011). The researchers also concluded that this study suggests that a patient-centered prevention program may be more cost-effective than traditional dental treatment for children affected by ECC in the long-term (Shenkin, 2011).

The etiology of ECC has been well established, but its complex, multifactorial nature makes effective intervention challenging because there is no simple causal pathway to target (Fejerskov, 2004). Consequently, numerous studies have evaluated the impact of behavior modification interventions in the prevention of ECC, but have shown limited success. Overall results from behaviorally-focused interventions are difficult to interpret and summarize owing to the variety of study designs and methodologies employed. Additionally, many of the ECC interventions that have been evaluated do not provide explicit information on the precise content and methods used in the provision of nutrition-related counseling. A summary of existing evidence regarding nutrition-related ECC interventions is provided in Table 2.4 – Overview of ECC Interventions.

Table 2.4

Overview of ECC Interventions

Design	Setting/ Population	Study Aim/ Intervention	Findings
Non-RCT (Holst & Kohler, 1975)	Lund, Sweden -Child Health Centers *Intervention:* 697 *Control:* 1479 -Age: 4yr	-To assess impact of diet and oral hygiene counseling on caries among 4-year-olds -Counseling provided by dentist and pediatrician on food, eating habits, oral hygiene and fluoride administration at 6,12, 24 months -Fluoride supplements given	-65% lower caries experience in the intervention versus controls -Significant reduction of caries; caries-*free* children increased from 26.4% to 42% -Unclear exactly what diet-related messages were conveyed during counseling
Prospective (R. L. Harrison & Wong, 2003)	Vancouver, Canada -Inner-city health clinic -60 mother /child pairs -Age: 2-18mo	-To assess impact of one-on-one counseling during well-child visits to health clinic -Vietnamese-speaking public health nurse educated Vietnamese parents -Lay community workers provided counseling via telephone follow-up calls one week post-clinic visit. Up to 4 follow-ups over 7 years	-Mothers who had ≥1 counseling visit reported less use of daytime and sleep-time bottles, and their children had lower ECC prevalence -Findings show promise that one-on-one counseling by lay community workers can facilitate adoption of healthful behaviors and can help reduce caries rates
RCT (Feldens et al., 2010)	Sao Leopoldo, Brazil -500 Mothers of single, full-term children -340 completed 4yr follow-up *Intervention*: 141 *Control:* 199	-To evaluate effect of home nutrition counseling on ECC/ S-ECC occurrence at age 4 -Monthly home visits up to 6 months; then months 8, 10, 12 -Advice by undergraduate nutrition students on healthy feeding practices during first year: exclusive breastfeeding up to 6 months; not to use bottle/breastfeeding as pacifiers; advice against added sugars in fruits,	-69.3% controls but only 53.9% intervention had ECC -Home counseling reduced ECC incidence by 22% (RR 0.78; 95% CI 0.65-0.93) - S-ECC incidence reduced by 32% (RR 0.68; 95% CI 050-0.92) - Mean number of dmft lower for intervention group (3.25) than controls (4.15) - Home nutritional counseling during first year of life decreased ECC incidence/ severity at age 4 - Future addition of oral hygiene instruction may improve

Design	Setting/ Population	Study Aim/ Intervention	Findings
		porridge, juices and milk, as well as giving soft drinks and snacks	outcomes
Cross-Sectional (Reisine & Litt, 1993)	Connecticut -Head Start Program -481 children -369 completed interview -Age: 3yr	-To assess effect of psychosocial variables (life stress, self-efficacy, locus of control) on clinical measures of ECC (S. Mutans, tooth decay) -Oral examination by dentist -Parent interview by research assistant (brushing habits, sugar intake, stressful life events, dental event locus of control, perceived dental self-efficacy)	- Findings confirm education alone is not sufficient to elicit preventive dental behaviors and improve oral health - Behavioral modification methods necessary to promote better oral health -External locus of control, lower income, more knowledge about tooth decay and higher stress correlated with greater caries risk
Historical Control Trial (Minah et al., 2008)	Baltimore, MD -Pediatric primary care clinic serving low-income residents -219 healthy children -Age: 6-27mo *Prevention*: 6-15mo compared at end with C*omparison:* 12mo older (18-27mo)	-26 month trial -To evaluate effect of risk-based caries prevention program which included: fluoride varnish, dental health counseling, verbal/written education on ECC prevention, referral for treatment, recalls if necessary -Counseling provided by full-time dental personnel	-Prevention group at last recall had lower mean caries (0.1 vs. 1.29, p=.01) and over 8-fold less MS than comparison at initial visit -Findings support dental health as a part of early pediatric care -ECC can be controlled and reduced -High patient volume at medical clinic, dental care provider efficient/ effective means for interventions - Prevention measures reduce ECC in low SES infants and toddlers -Study supports prevention programs at urban primary care pediatric clinics - Unclear exactly what content was included in counseling

Design	Setting/ Population	Study Aim/ Intervention	Findings
RCT (Freudenthal & Bowen, 2010)	Southeast Idaho -Women, Infants and Children (WIC) Program -72 mothers with ≥1 child -Age: 6-24mo *Treatment:* 40 *Control:* 32	-Evaluate if individualized oral health motivational interviewing (MI) promoted positive changes in ECC risk-related behaviors -No education in control -One 20-30 minute MI intervention by trained researcher, with follow-up phone calls at 1 and 2 weeks post-MI to promote changes - Information about oral health provided if appropriate during MI session without advice or opinion in form of a menu	-Positive changes in treatment group in frequency teeth cleaned or brushed (p = 0.001) and use of shared eating utensils (p = 0.035) -Change in other cariogenic feeding practices/use of sweets to reward/ modify behavior not significant -Results may be limited by short duration of MI intervention -Findings suggest novel interventions (e.g., MI) are needed to promote healthy practices to lower ECC risk
RCT (Hietasalo et al., 2009)	Pori, Finland - 497 children with ≥1 active initial carious lesion *Intervention:* 250 *Control:* 247 -Age: 11-12yr	-To evaluate effect of an individually designed patient-centered program; counseling by trained dental hygienists -3.4 year follow-up -Intervention received toothbrushes, fluoride toothpaste, fluoride and xylitol lozenges; nutrition and oral hygiene counseling (M = 12.4) -Control group received preventive fluoride varnish up to two times -Both groups exposed to community-level oral health promotion	-Intervention had more decayed surfaces averted -DMFS cost increment reduced by 44.3% -Initial cost for experimental group higher, but costs decreased with time; less than control last 2 years - Suggests that in the long term, a patient-centered prevention program may be more cost-effective than traditional services - Study did not identify specific benefit of any single intervention component, so precise contribution of diet counseling unclear
Review (Rebecca Harris et al., 2012)	-Includes evidence from randomized control trials among all age groups	-To assess the effectiveness of one-to-one dietary interventions within dental care settings in changing dietary behaviors	-Findings suggest some evidence that one-to-one dietary interventions within a dental setting to promote diet-related behavior change -Emphasis on general rather than oral health is effective to promote behavior change -Little evidence shows interventions aimed at ECC are effective, but mainly due to a paucity of studies and poor

Design	Setting/ Population	Study Aim/ Intervention	Findings
			methodological designs
Review (Norman Tinanoff & Reisine, 2009)	N/A	-To provide an update and overview of current evidence regarding ECC prevention since Surgeon General's Report on Oral Health in 2000	-Behavior change via intense counseling or motivational interviews may reduce ECC -Nutrition education focuses on importance of reducing exposures to sweet foods/ hidden sugars - Education is necessary, but not sufficient for behavior change -Diet counseling aims: choose diets with low or non-cariogenic snacks, limit sweet foods to mealtimes, brush after sugar exposures - Guidance must be realistic, based on current behaviors - Diet modifications only made over time with repetition/reinforcement - Goal is lifelong habits, that promote general/oral health

Despite the varying degrees of success and design methods, the current body of literature on behavioral interventions for ECC prevention suggests that employment of multiple inputs is essential to elicit desired behavior change. As with most complex diseases, if prevalence rates and severity of ECC are to be effectively reduced, a multidimensional approach to disease treatment, with a focus on prevention via behavioral modification, must be applied.

2.7 – Diet and Oral Health Recommendations for Children

The AAPD recognizes the influential impact of diet on ECC. Therefore, recommendations for reducing caries risk include several nutrition-related goals. The AAPD recommends that infants, children, and adolescents adopt a diverse and balanced diet based on United States Department of Agriculture (USDA) dietary guidelines (Mobley et al., 2009).

2.7.1 – USDA dietary guidelines. The 2010 Dietary Guidelines for Americans form the basis for the federal government's nutrition education programs and dietary advice that is provided by nutrition and health professionals. The 2010 guidelines provide key messages regarding which food groups Americans should increase in their diet, as well as which food groups they should consume less of. The three main recommendations are to balance caloric intake with physical activity to manage weight; consume more: fruits, vegetables, whole grains, fat-free and low-fat dairy products, and seafood; consume less: sodium, saturated and trans fats, cholesterol, added sugar (including sugary drinks), and refined grains (US Department of Agriculture). The overall recommendations about what to eat, and how much to eat has not changed, although the 2010 guidelines provide recommendations regarding overall dietary patterns, rather than exact amounts of foods that should be consumed from each food group (US Department of Agriculture).

The 2005 Dietary Guidelines included specific recommendations on amounts of each food group to consume, and recommended 2 cups of fruit, 2.5 cups of vegetables, 6 ounces of grains, 5.5 ounces of protein foods, and 3 cups of dairy per day (based on 2000 calories) (US Department of Agriculture). These recommended intake amounts are still relevant under the new guidelines, but it should be noted that amounts differ based on total calorie needs of the individual. Daily calorie needs vary greatly among individuals, depending on sex, age, height, weight, physical activity and health-related factors. For children aged 2 to 5 years, calories may range from approximately 1000 to 1600 calories per day to support rapid growth and development (US Department of Agriculture).

The USDA has adopted the MyPlate illustration to emphasize the 2010 guidelines (Figure 2.4 – USDA MyPlate Illustration). The MyPlate illustration is designed to remind Americans of the following key messages: make half your plate fruits and vegetables; make at least half your grains whole grains; switch to fat-free or low-fat (1%) milk (US Department of Agriculture). The use of this visual representation and general guidelines on dietary patterns, versus exact amounts, utilizes a directional rather than quantitative approach to dietary recommendations (US Department of Agriculture).

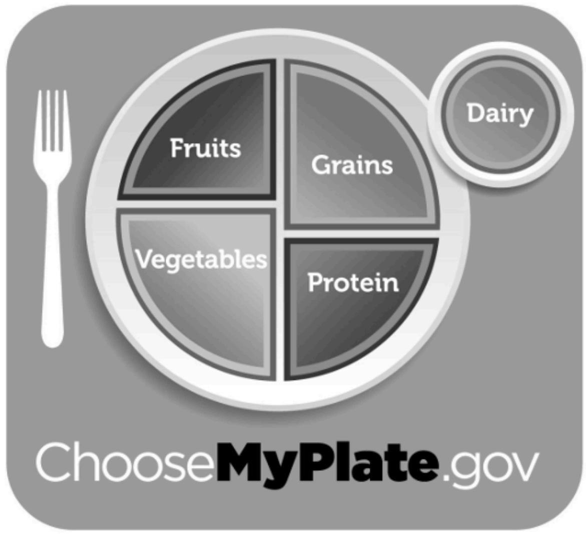

Figure 2.4. USDA MyPlate Illustration.
(US Department of Agriculture)

2.7.2 – Oral health recommendations. The AAPD has established several key recommendations for promoting and maintaining optimal oral health among children to effectively reduce ECC. These recommendations include both oral self-care and diet-related behavior guidelines. The ECC prevention strategies recommended by AAPD include minimizing transmission of cariogenic bacteria; implementing early oral hygiene; establishing a dental home; avoiding cariogenic diet-related behaviors, and collaboration among child health professionals (American Academy of Pediatric Dentistry, 2011).

Minimizing transmission of cariogenic bacteria. This recommendation consists of two parts: reduction of parent/sibling cariogenic bacteria levels and reduction of saliva-sharing activities (American Academy of Pediatric Dentistry, 2011). Studies evaluating MS levels in mothers, as they relate to child ECC experience, suggest that children most often share common strains of MS with their primary caregivers (Berkowitz, 2003; Milgrom et al., 2009). Studies have also suggested that high maternal MS levels are highly correlated with early acquisition of MS by children, and increased risk of ECC experience (American Academy of Pediatric Dentistry, 2011). Acquisition of MS has been identified as occurring most often vertically from primary caregiver (often the mother) through salivary contact (e.g., sharing utensils/drinking cups, pre-chewing food, orally cleansing pacifiers, physical contact) (American Academy of Pediatric Dentistry, 2011; Berkowitz, 2003; Fisher-Owens et al., 2007; Milgrom et al., 2009). However, it is possible for MS to be acquired via horizontal transmission as well (e.g., between other members of the family, or children in daycare) (American Academy of Pediatric Dentistry, 2011; Berkowitz, 2003). It is well documented that maternal and family caries experience is highly related to child caries risk, further bolstering the implication that MS is often vertically transmitted is the manner described (Berkowitz, 2003; Horowitz, 2004). Therefore, minimization of saliva-sharing activities and reduction of MS levels among family members is highly recommended to help reduce initial transmission and subsequent proliferation of caries-causing MS (American Academy of Pediatric Dentistry, 2011).

Implementing early oral hygiene. Oral hygiene practices are encouraged to begin no later than the time of primary tooth eruption (American Academy of Pediatric Dentistry, 2011). Proper oral self-care habits help to minimize accumulation of dental plaque and aid in the promotion of optimal oral pH balance. Tooth brushing after intake of foods and beverages encourages rapid clearance of fermentable carbohydrates from the oral cavity, thereby minimizing exposure to the demineralization processes. Education on appropriate use of fluorides should be encouraged (N. Tinanoff & Palmer, 2000). It is recommended that tooth brushing with fluoridated toothpaste be performed by a parent twice a day, using a soft tooth brush. As previously noted, insufficient tooth brushing has been indicated in development of ECC, thus parental assistance is recommended until children are capable of thoroughly brushing independently (Fisher-Owens et al., 2007). Research on tooth brushing habits related to ECC has shown that children whose parents assist with tooth brushing beyond 3 years of age have significantly fewer decayed, missing or filled primary teeth (dmft) (Fisher-Owens et al., 2007; Marsh, 1991; Pieper et al., 2012). Children under the age of 2 years who are considered at moderate or high risk of ECC, should use a “smear” of fluoridated toothpaste; whereas all children may begin using a “pea-size” amount of fluoridated toothpaste between the ages of 2 to 5 years (American Academy of Pediatric Dentistry, 2011).

Establishing a dental home. The AAPD recommends that a dental home be established within 6 months of the eruption of the first tooth and no later than 12 months of age to conduct a caries risk assessment provide referral to additional health care providers as needed, and provide anticipatory guidance and education to parents (American Academy of Pediatric Dentistry, 2011). The AAPD recognizes that after the age of 2 or 3 years, children often see their dentist more frequently than their primary medical provider (Nainar & Mohummed, 2004b) (American Academy of Pediatric Dentistry, 1993-2012). Thus, provision of a dental home allows for early intervention of ECC through frequent access to a patient-centered oral care environment. Early intervention allows for provision of timely anticipatory guidance to create a basis for ECC prevention and allows for developmentally appropriate oral hygiene and diet-related recommendations to be provided (Fitzsimons et al., 1998). Furthermore, the dental home would likely provide a much needed service to reach children at the highest levels of risk, who currently do not receive the benefits of routine dental care. Despite the benefits of establishment of a dental home, the feasibility of widespread adoption of this recommendation is limited at this time. Due to barriers associated with the current dental system, cost, and limited availability of practitioners, large scale implementation of a dental home would require cooperation with other agencies that serve the needs of young children (B. Edelstein, 2008). Efforts to effectively target those at greatest risk for disease must be made, with a focus on epidemiologic, health service, and demographic trends (B. Edelstein, 2008). Moreover, increased public awareness and enhanced professional engagement are essential if the concept of a dental home is to be widely accepted (B. Edelstein, 2008).

Avoiding cariogenic diet-related behaviors. The frequency of consuming fermentable carbohydrate-containing foods/beverage items, the characteristics of the items consumed (i.e., consistency, form, oral retentiveness), and the intake patterns (i.e., between-meal vs. meal, prolonged vs. rapid) are all important factors involved in the diet-ECC relationship (C.A. Palmer, et al., 2010; Gustafsson et al., 1954; Heller et al., 2001; Krasse, 2001; Mobley, 2003; Sanders, 2004; Touger-Decker & van Loveren, 2003).

The AAPD recommends that children avoid high frequency consumption of foods/beverage containing fermentable carbohydrates, including sugar-containing beverages (e.g., juices, soft drinks, sweetened tea, flavored milk) (American Academy of Pediatric Dentistry, 2011). There is strong evidence to suggest that frequent intake of sugars from either foods or beverages, beyond four times a day, has been shown to increase risk of dental caries; therefore intake of free sugars from these sources should be limited to no more than four times a day (Rebecca Harris et al., 2012; Hooley et al., 2012; Moynihan & Petersen, 2004). Furthermore, in regard to beverage intake, the American Academy of Pediatrics (AAP) recommends that children between the ages of 1 to 6 years consume no more than four to six ounces of juice per day (Savage et al., 2007). Despite this recommendation, consumption patterns among children appear to be much higher, ranging from 9.5 ounces to over 14 ounces of juice per day (Savage et al., 2007). Emphasis of ECC-related diet recommendations should be placed on limiting frequency of sugar intake, and parents should be advised not to give powdered beverages or soft drinks to infants (Nainar & Mohummed, 2004b). Generally, sweetened beverages that are consumed during meals are not highly cariogenic, however, when they are held in the mouth for prolonged periods of time, or that are slowly sipped over an extended period of time the cariogenic potential is greatly increased (American Academy of Pediatric Dentistry, 2011; Hague, 2011; Hooley et al., 2012; Mobley, 2003; C. Palmer, 2010; Touger-Decker & van Loveren, 2003).

AAPD recommendations also state that infants should not be put to sleep with any sugar-containing beverages, that ad libitum breastfeeding should be avoided after primary tooth eruption and introduction of other dietary carbohydrates has begun, and that parents should encourage infants to drink from a cup as they approach their first birthday, with complete weaning from the bottle occurring between 12 to 18 months of age (American Academy of Pediatric Dentistry, 2011) (Fitzsimons et al., 1998). Prolonged use of bottles and no-spill training cups is discouraged as these feeding practices result in slow oral clearance of fermentable carbohydrate, particularly when they occur during a time when salivary flow rate is already reduced (i.e., during sleep), therefore they greatly increase the frequency and duration of enamel demineralization (Kawashita et al., 2011).

Education on diet-related ECC risk factors should include the role of sugary foods and beverages on caries risk (Mobley et al., 2009). Nutrition education and counseling for ECC reduction should focus on illuminating the hidden sources of sugars in the diet, and on limiting intake of overt sources of sugars to mealtimes only (N. Tinanoff & Palmer, 2000). Encouragement of healthful feeding practices is an important component of ECC reduction efforts, as establishment of sound eating practices may help encourage appropriate choices later (N. Tinanoff & Palmer, 2000). Appropriate nutrition early in life is a major determinant to oral and systemic health later in life (N. Tinanoff & Palmer, 2000). Recommendations for appropriate anticipatory guidance on reducing diet-related ECC risk during infancy/toddlerhood include: encouraging a healthy diet with a limited number of exposures to sugary snacks/beverages; emphasizing the importance of frequency of exposures on ECC risk (i.e., encouraging no more than 3 meals and 2 snacks daily); reminding parents of cariogenic feeding practices (e.g., putting a baby to bed with a bottle of juice); encouraging weaning from bottle by 12 months of age; and encouraging oral hygiene practices to increase saliva and reduce oral clearance time (Francisco et al., 2007).

Research on effective programs that provide nutrition counseling for ECC prevention, suggests that counseling incorporate both general aspects of positive health behaviors as well as those directly linked to oral health (Moynihan & Petersen, 2004). This is important to note, because research has shown that free access to sweetened beverages (including juice) and snacks over the course of the day favors intake of nutrient-poor foods and not only increases risk of ECC, but increases risk of childhood obesity as well (Marshall et al., 2005).

Healthcare professional collaboration. Research indicates that partnerships between physicians and dentists are urgently needed in order to combat rising rates of ECC (Berg & Stapleton, 2012). ECC is multifactorial in nature so a multidisciplinary approach to care is appropriate. The AAPD recognizes this fact, and therefore recommends that dentists work with other medical and health providers to ensure that all infants and toddler have access to proper care (American Academy of Pediatric Dentistry, 2011). Evidence suggests that some dentists may be reluctant to partner with physicians because of a belief that oral health may not predict overall health (Berg & Stapleton, 2012). However, research has suggested that dental professionals often lack familiarity and comfort working with young children, as many training programs provide little exposure to preschool children, so collaboration with other health providers treating children may be viewed positively(Weinstein, 1998). Pediatricians, pediatric nurse practitioners and dietitians also hold the potential to successfully support dental professionals via collaborative efforts to provide preventive anticipatory guidance to parents of young children (Marshall et al., 2003).

The Association of Nutrition and Dietetics (AND) published a position statement on the connection between oral health and nutrition, and asserted that collaboration between Registered Dietitians (RDs) and dental professionals is recommended for oral health and disease promotion (Touger-Decker, 2007). Although the AAPD recommends that pediatric dentists play a role in providing dietary counseling to patients in conjunction with other preventive services, dentists may find it advantageous to collaborate with a Registered Dietitian (RD) for such care (Nainar & Mohummed, 2004b). Research suggests that dental professionals may not feel confident providing dietary advice, and suggests that inter-professional partnerships be established to effectively promote caries prevention (Cashmore, Noller, Ritchie, Johnson, & Blinkhorn, 2011). This partnership may be facilitated via patient referrals from RDs to pediatric dental specialists, and likewise, referrals from dental specialists (Fitzsimons et al., 1998). The AND position statement suggests that practitioners of both disciplines learn to provide screening, basic education, and referral to each other as part of a comprehensive patient care system (Touger-Decker, 2007).

RDs should incorporate basic oral health education and screening for ECC risk in their counseling, and dental professionals should embrace calculation and monitoring of body mass index-for-age (BMI/age) percentiles of their patients for referral of high/low BMI/age children to an RD if needed (Touger-Decker, 2007; Vann, Bouwens, Braithwaite, & Lee, 2005). The Centers for Disease Control and Prevention (CDC) defines a healthy weight for children as falling between the 5th and 85th percentile on a BMI/age percentile growth chart (Centers for Disease Control and Prevention). Children with BMI/age percentiles below the 5th percentile are considered underweight, those between the 85th and 95th percentile are considered overweight, and children at or above the 95th percentile are considered obese (Centers for Disease Control and Prevention). Because oral and systemic health are so closely linked, and there is evidence to suggest that oral health may influence weight status, collaborative efforts between the fields of nutrition and oral health will foster effective strategies for disease prevention and management as well as health promotion (Touger-Decker, 2007).

As discussed previously, several studies have identified an association between dental caries and obesity in childhood (Reifsnider et al., 2004; Tuomi, 1989; Willershausen et al., 2004). Despite the recognition of positive relationships between anthropometric measures and oral health, there is limited evidence on the existence of a causal relationship (Touger-Decker, 2007). However, the relationship between body weight and oral health is believed to be a result of shared etiological risk factors, including health habits, inflammatory markers, hormonal factors, and related comorbidities (Touger-Decker, 2007).

Obesity is a chronic disease that has received significant public attention and has become a primary target for reduction and prevention efforts in the United States. There is some evidence to suggest obesity prevalence rates among children may be leveling off, but the statistics are still quite alarming (Centers for Disease Control and Prevention, 2009; Ogden, Carroll, & Flegal, 2008). Nearly 1 in every 5 children between 6 and 19 years of age is obese, with a BMI/age $\geq 95^{th}$ percentile (Centers for Disease Control and Prevention, 2009; Ogden et al., 2008). Obesity has a tremendous impact on quality of life and quality of systemic health, with strong correlations with heart disease, high blood pressure, type II diabetes, arthritis, and some cancers (Centers for Disease Control and Prevention, 2009).

There is evidence to suggest that the first 3 years of life may lay the foundation for obesity, therefore timely nutrition intervention is essential and collaboration between multiple healthcare disciplines can facilitate prompt intervention (American Academy of Pediatric Dentistry, 1993-2012; Vann et al., 2005). Among the multitude of benefits related to early provision of multidisciplinary care, is the opportunity to help children avoid serious nutrition related conditions, including childhood obesity (Adair, 2004). Dental professionals should therefore refer patients identified at-risk by BMI/age percentiles during their early dental visits to an RD for targeted nutrition counseling (Vann et al., 2005). RDs hold the unique skills and knowledge to address the challenges associated with optimal weight management, but should also acquire and develop skills necessary for counseling in support of oral health as well (Mobley et al., 2009). RDs should provide targeted information and counseling to foster positive dietary and dental health behaviors among parents and primary caregivers of young children early in life (Fitzsimons et al., 1998). Proper collaboration between nutrition and dental health professionals will help promote optimal oral health and encourage systemic disease prevention (Fitzsimons et al., 1998; Touger-Decker, 2007).

2.8 - Early Childhood Caries Risk Assessment Tools

A major component of both primary and secondary prevention of ECC is early detection efforts, such as screening methods and risk assessment tools to identify individuals at highest risk. Risk assessment is defined as an estimation of the likelihood that an event will occur in the future (Francisco et al., 2007). As such, development of effective risk assessment methods is essential to resolving the nation's "oral health crisis" ("Oral health in America: a report of the Surgeon General," 2000).

Effective risk assessment should be the first step in implementing a comprehensive intervention protocol for identifying characteristics related to ECC to help identify those at risk and to clarify their oral health intervention needs (Francisco et al., 2007). Early identification of caries risk and initiation of subsequent management is essential, since ECC is a known predictor of caries in the permanent dentition (Francisco et al., 2007; Helm & Helm, 1990;Tinanoff & Reisine, 2009). Additionally, the strong correlation between ECC and systemic health problems adds credence to the use of risk assessment tools.

Risk assessment tools allow for the identification of reliable predictors of oral disease, and assist oral health and general health practitioners in becoming actively involved in identifying and referring at-risk children for treatment (American Academy of Pediatric Dentistry, 2011/2012). A survey of dental professionals revealed that the great majority, approximately 73 percent, utilize some form of caries risk assessment in their practice; however, only 14 percent reported using a specific risk assessment tool (Pediatric Oral Health Research and Policy Center, 2012). This finding suggests that dental health practitioners may be using informal and potentially inconsistent risk assessment evaluation methods, which may not be considered accurate or valid measures.

Because ECC is a complex, multifactorial disease, effective risk assessment models must be broadly defined beyond the biologic parameters of the classic caries model, to involve a combination of factors associated with disease development and progression (Pediatric Oral Health Research and Policy Center, 2012). ECC risk assessment models should incorporate evaluation of a multitude of ECC-related factors, including diet-related behaviors, fluoride exposure, susceptibility of the individual, socioeconomic status, cultural influences, and oral health behaviors (American Academy of Pediatric Dentistry, 2011/2012). Through inclusion of the etiological factors related to ECC, risk assessment tools can help determine the likelihood of caries incidence (i.e., emergence of a new cavitated or incipient lesion) or the likelihood that there will be a change in the activity or size of lesions already present (i.e., disease process will progress, be arrested, or reverse) (American Academy of Pediatric Dentistry, 2011/2012). With this ability, the risk assessment tool can help clinicians identify caries in its earliest sates (i.e., white spot lesion) and consequently assist in the prevention of progression to frank cavitation (American Academy of Pediatric Dentistry, 2011/2012). Effective ECC risk assessment allows the dental clinician to determine the balance of protective factors appropriate for treatment of disease at varying levels of risk, thereby informing the design and implementation of a targeted approach in the management of the disease process (Francisco et al., 2007).

According to the AAPD, risk assessment: (1) fosters treatment of the disease, as opposed to treating the outcome of the disease; (2) furthers understanding of disease factors relevant for a specific patient, and aids in individualization of prevention efforts; (3) assists in determining appropriate preventive or restorative treatments; and (4) anticipates the likelihood of caries progression or stabilization (American Academy of Pediatric Dentistry, 2011/2012). In order to implement an effective ECC risk assessment strategy, information must be collected via interview of the child's parent/primary caregiver regarding variables such as socioeconomic status, parental and sibling history of caries, and child feeding practices (Francisco et al., 2007; Freudenthal & Bowen, 2010). Additional information should be also collected about the child's physical risk factors and bacterial cultures, if indicated (Francisco et al., 2007).

Although dietary habits that increase the quantity and frequency of cariogenic foods (fermentable carbohydrates) is a known risk factor for ECC, oral health professionals rarely assess patients' diet-related behaviors (Marshall, 2009). The assessment of these ECC diet-related factors is an essential component of preventive care, but due to time and resource limitations, it is often forgone (Marshall, 2009). Existing risk assessment tools for ECC, though not consistently utilized in practice, incorporate very limited assessment of dietary intake, assessing only frequency of between-meal snacks/beverages and bottle exposures of sugary beverages. Ideally, ECC risk assessment tools should include evaluation of several key areas in the diet assessment portion of the interview, including frequency of dietary exposures (meals and snacks), the structure of meals and snacks, and the manner and frequency of sugared beverage intake (sugared beverages include 100 percent juice, juice drinks, soft drinks, sports drinks, energy drinks, and sugared coffee and tea) (Marshall, 2009).

Traditional assessment of dietary intake by an RD is somewhat labor intensive, requires specific training to implement, and is time consuming, thus making it difficult for utilization by a dental clinician. One useful method of dietary assessment for the evaluation of an individual's dietary intake is a 24-hour recall. A 24-hour dietary recall is an interviewer-administered dietary assessment tool designed to gather information about food and beverage intake patterns via open-ended questions (Marshall, 2009). Completion of the 24-hour dietary recall involves asking a patient to recall and state all foods, beverages and snacks consumed during the previous 24 hours, from the time they arose from bed to the time they went to sleep. The traditional 24-hour recall method involves multiple passes (review of data) with the participant, to collect information on portion sizes consumed, preparation methods, and ingredients. Utilization of a 24-hour dietary recall allows for collection of detailed dietary intake data for one full day, which may serve as a model for typical daily intake patterns. However, the limitation of capturing a single day's intake, which does not account for fluctuations in dietary intake patterns over the course of several days, must be recognized (Radford et al., 2000). Additionally, the accuracy of 24-hour dietary recalls may be challenged, as they rely on an individual's memory to recall all foods/beverages consumed (Moynihan & Petersen, 2004; Radford et al., 2000). Because the traditional multiple-pass 24-hour recall is time consuming, and collects information that may not be relevant to ECC (though relevant to general nutrition counseling), this method of dietary assessment is not ideal for use in ECC risk assessment.

Given the challenges faced by many oral health practitioners (i.e., limited time and resources), it is easy for them to lose sight of dietary concerns, and instead focus on immediate issues, such as restoration of decayed teeth or alleviation of oral pain (Marshall, 2009). Therefore a streamlined 24-hour dietary recall, or simply asking patients questions regarding typical food groups consumed and general intake patterns may help oral health practitioners collect information on diet-related ECC risk factors (Marshall, 2009). The ability to provide appropriate nutrition counseling within the oral health care setting, requires prioritization of needs, an efficient mode of diet assessment, a working knowledge of diet and oral health relationships, and confidence in this knowledge (Cashmore et al., 2011; Marshall, 2009).

Numerous methods have been developed to assess caries risk. The table below summarizes the pros and cons of several ECC risk assessment methods, with a more detailed overview of each presented in the following section. (Table 2.5 – Comparison of ECC Risk Assessment Tools).

Table 2.5

Comparison of ECC Risk Assessment Tools

Caries Risk Assessment Tools	Pros	Cons
Informal Caries Risk Assessment (practitioner specific)	▪ Easy to implement ▪ Intuitive for busy providers	▪ Unstructured and potentially inconsistent ▪ Inclusion of particular risk criteria based on intuition rather than data
Diet Assessment of Caries Risk	▪ Easy to use ▪ Provides thorough assessment of diet-related risk factors	▪ Does not assess non-dietary caries risk factors ▪ Must be utilized in conjunction with another caries risk tool in order to provide a comprehensive assessment of risk
CAMBRA	▪ Simple and straightforward to use	▪ Factors identified in CAMBRA interviews shown to be related to caries but predictive utility not tested ▪ Point in time assessment ▪ Preventive/recall recommendations for low-risk children do not account for rapidly changing circumstances that affect risk ▪ Includes limited dietary assessment component
Cariogram	▪ Comprehensive and exhaustive approach ▪ Includes questionnaire, interview, estimation of oral hygiene and saliva sampling ▪ Provides visual and interactive risk review	▪ Inclusion of salivary test may pose a barrier to implementation ▪ Costly and time consuming ▪ Requires use of computer with specialized software ▪ Risk scoring based on practitioner judgment
AAPD CAT	▪ Simple to use ▪ Easily integrated into clinical record	▪ Point in time assessment; predictive utility not clinically tested ▪ Incorporates limited dietary assessment component
Saliva Testing (MS)	▪ Statistically significant relationship between MS and future caries	▪ Requires specialized equipment ▪ Can be expensive and often not reimbursed by insurance ▪ Does not account for non-biological, behavioral risk factors

An example of a currently utilized risk assessment tool is the Diet Assessment of Caries Risk tool, which was developed at the University of Iowa (Appendix A – Diet Assessment of Caries Risk) (Marshall, 2009). This tool was designed to assist oral health care professions efficiently assess diet-related factors associated with caries and to facilitate conversations regarding dietary advice with patients (Marshall, 2009). The tool provides a simple method of diet assessment by evaluating responses to questions regarding number of meals/snacks consumed daily, meals/snack structure, sugared beverage intake (quantity and frequency), length of exposures, and drinking style (Marshall, 2009). Although it incorporates several important dietary risk factors for ECC, this tool does not evaluate non-dietary risk factors. Therefore, it would need to be used in conjunction with another caries risk assessment tool in order to provide a comprehensive assessment.

Another risk assessment tool that has been developed for ECC prevention is the Caries Management by Risk Assessment (CAMBRA 0-5) (Appendix B – Caries Management by Risk Assessment (CAMBRA 0-5)). This tool was specifically designed for use within a busy dental practice to assess risk of caries among children age 0 to 5 years (Francisco et al., 2007). This tool is a single-page questionnaire that includes sequential assessment of five key areas of assessment via parent interview and clinical examination: caries risk indicators (i.e., previous caries in child or parent, socioeconomic status, dental home status; caries risk factors (biological and behavioral); protective factors (non-biological); protective factors (biological); caries risk indicators/factors (i.e., physical assessment of caries risk). If several of these disease indictors are present, clinicians are instructed to perform a bacterial culture to identify the presence of oral bacteria commonly associated with ECC, mutans streptococci (MS) and lactobacillus, on both the mother/primary caregiver and child to assess the need for antibacterial therapy (Francisco et al., 2007). Although the CAMBRA is brief and easy to administer, it incorporates a very limited dietary assessment component. Additionally, the clinical utility of the CAMBRA for caries prevention may be limited by the lengthy preventive treatment and recall recommendations provided for children who score at low risk. This limitation may prevent early identification of rapidly changing factors that may significantly affect caries risk (Pediatric Oral Health Research and Policy Center, 2012).

A third caries risk assessment tool is a computer-based software program called Cariogram (Appendix C – Cariogram Risk Assessment) (Bratthall & Hansel Petersson, 2005). This tool was designed to address the multifactorial nature of ECC by illustrating the interactions between nine key factors related to caries risk. The software guides the clinician through collection of data by prompting the clinician to assign a risk score to each of the key variables, including diet, plaque, caries experience, bacterial counts (assessed via salivary testing) and saliva secretion (Bratthall & Hansel Petersson, 2005). The Cariogram software then illustrates the interaction of these in a colorful pie chart to facilitate discussion between clinician and regarding ways to reduce caries risk (Bratthall & Hansel Petersson, 2005). By providing a visual representation of caries risk, the Cariogram program may provide a unique opportunity for patient engagement and education. However, the Cariogram risk scores are largely based on clinician interpretation and judgment, thus increasing the potential for scoring inconsistency. Additionally, the Cariogram program has been critiqued for being costly and time consuming to administer, as it requires purchase of specialized software, use of a computer, and incorporates salivary MS testing (Pediatric Oral Health Research and Policy Center, 2012).

A fourth, but perhaps most commonly used, ECC risk assessment tool is the AAPD Caries-Risk Assessment Tool (CAT) (Appendix D – AAPD Caries –Risk Assessment Tool (CAT)) (American Academy of Pediatric Dentistry, 2011/2012). This tool was designed to be a simple to use tool that could be easily integrated into the existing patient health record (Pediatric Oral Health Research and Policy Center, 2012). The CAT is a one-page assessment form (actually several forms, each age-specific) which characterizes caries risk in regard to a number of recognized risk factors, including biologic/behavioral factors, protective factors and clinical findings (American Academy of Pediatric Dentistry, 2011/2012). The tool includes recommendations for treatment planning based on calculated risk, and incorporates risk factors from clinical conditions, environmental characteristics and general health conditions (American Academy of Pediatric Dentistry, 2011/2012). The CAT evaluates risks according to socioeconomic status, diet (sugar and beverage consumption), special health care needs, recent immigrant, fluoride use, oral hygiene, dental home, presences of lesions, active white spot lesions or enamel defects, salivary flow and restorations (American Academy of Pediatric Dentistry, 2011/2012). Despite its widespread use, the predictive utility of the CAT has not, until recently, been clinically validated (Pediatric Oral Health Research and Policy Center, 2012). A recent evaluation of the clinical utility of the CAT tool for successful identification of children at risk for caries, concluded that the CAT alone, was not as accurate or clinically useful as MS testing for assessing caries risk (Yoon, et al., 2012). Moreover, the CAT, like several of the other ECC risk assessment tools, incorporates a limited dietary assessment component.

In addition to the aforementioned questionnaire-style risk assessment tools, clinicians often utilize microbial assessment tools in their evaluation of children's ECC risk. Although there are numerous oral bacteria, mutans streptococci (MS) is the primary microorganism associated with ECC and is an important predictor (Loesche, 1969; Reisine & Litt, 1993; Tanzer et al., 2001; Norman Tinanoff & Reisine, 2009). MS are ubiquitous in populations worldwide, have been highly correlated with the caries process, even at low colonization levels, and colonization of MS is necessary for caries initiation (Fejerskov, 2004; Loesche, 1969; Tanzer et al., 2001) (Norman Tinanoff & Reisine, 2009).

There are several types of saliva tests available to clinicians in the Unites States for the measurement of MS and subsequent evaluation of caries risk (Fontana & Zero, 2006). These tests are designed to easily estimate bacterial levels in saliva, to aid clinicians in identifying patients with high salivary bacterial load (thus suggesting high risk for caries) (Fontana & Zero, 2006). MS saliva testing has been identified as a relatively simple and cost-effect method of ECC risk evaluation, and these tests have been useful in clinical settings to easily identify caries risk, to motivate patients to make desired changes, and to monitor changes in oral hygiene practices (Fontana & Zero, 2006; Milgrom et al., 2009). The commercial kits that are available for MS assessment use a selective growth media, inoculated with saliva, to promote the proliferation of MS bacteria and the formation of MS colony forming units (Kimmel & Tinanoff, 1991). These MS testing kits allow for evaluation of MS levels via four levels of classification: low, moderate, high, and very high, which represent approximate logarithmic increments in MS titers in saliva (Hildebrandt & Bretz, 2006; Kimmel & Tinanoff, 1991; Yoon et al., 2012).

The accuracy of the salivary tests for MS in predicting future caries in the whole population is less than 50 percent, and tests to evaluate lactobacilli are less predictive (Alfano et al., 2001; Reich, Lussi, & Newbrun, 1999; Russell, MacFarlane, Aitchison, Stephen, & Burchell, 1991; Wilson & Ashley, 1989). However, these results may be misleading in evaluation of ECC risk because screening for MS in saliva has only been used to a limited degree in young children compared with its use in older children because of difficulty collecting stimulated saliva in this age group; yet these are the children most impacted by ECC (Alaluusua & Renkonen, 1983; Anasi et al., 2000; Kohler, Andreen, & Jonsson, 1988; Radford et al., 2000; Yoon et al., 2012). There is evidence to suggest that MS tests may be more predictive among children at-risk for ECC, rather than adults. Evaluations of sensitivity, specificity, and predictive values of MS testing have identified age as a clinically significant factor in the association between caries and MS levels, finding a stronger association between the two among younger children (Yoon et al., 2012). Additionally, an evaluation of assessment tools for ECC among low-income, Hispanic children, researchers found that salivary cultures of MS alone outperformed the CAT and variations of the CAT for both test accuracy and clinical usefulness, and that MS tests were the best performing screening tool within this population (Yoon et al., 2012). Another study that evaluated markers for identification of ECC among infants, 1 year of age (*n* = 1393), found that MS were isolated significantly more frequently among those infants with caries compared to caries-free infants (Radford et al., 2000). Moreover, these findings are supported by outcomes from two similar studies that evaluated MS measures among young children (2.5 years of age, and 1 to 2 years) (Anasi et al., 2000; Grindefjord et al., 1996; Radford et al., 2000). Overall, these studies support the use of MS saliva tests in the evaluation of ECC risk factors among young children.

2.9 - Development of MySmileBuddy

The AAPD recognizes the importance of early risk assessment in the prevention and management of ECC, however, the association acknowledges that there are no assessment tools, to date, that can ensure accurate categorization of children by risk or predict future caries experience through clinical application (Pediatric Oral Health Research and Policy Center, 2012). If risk for ECC is to be appropriately assessed, new tools must be developed to provide a more thorough, and clinically feasible, method of assessment.

The AAPD defines an ECC risk assessment tool as, “An instrument to determine an individual’s susceptibility to future dental caries, which is non-invasive, reproducible, has validity, is inexpensive, and relates to treatment and preventive therapy” (Pediatric Oral Health Research and Policy Center, 2012). The DECC study utilized an ECC risk assessment tool that was specifically developed to address each of the aforementioned AAPD requirements for effective assessment tools, entitled MySmileBuddy (MSB) (Appendix E – MSB Guide and Screenshots). MSB was designed to be a comprehensive ECC risk assessment tool able to address the gaps currently unfilled by previously developed tools. The project team that developed MSB reviewed preexisting ECC risk assessment tools and recognized the existence of multiple flaws and gaps in the tools that could be improved. The team determined that existing ECC assessment tools are flawed in that they often attempt to address all age groups in a single model, they do not appropriately evaluate the differential impact of individual- and population-level risk factors, and they are often unnecessarily complex (B. Edelstein, 2009-2011). A comparison of preexisting ECC risk assessment tool pros and cons may be found above in

Section 2.8 (Table 2.3 – Comparison of ECC Risk Assessment Tools). In order to improve upon existing ECC risk assessment tools and address the identified flaws, the MSB team sought to design a novel ECC assessment tool that would be simpler to administer, more clinically reliable, user-friendly, and one that is based on scientifically valid measures of ECC risk (B. Edelstein, 2009-2011).

2.9.1 – Model and theoretical framework. MSB was developed under an RC1MD00425701 study funded under the ARRA Challenge Grant Program on a proposal entitled Bio-Behavioral Chronic Disease Management by Families of Young Minority Children (B. Edelstein, 2009-2011). A primary aim of which was to create a computer-based application for a portable electronic device (iPad) that could be administered to parents/primary caregivers of young children by a community health worker. The iPad-based program, MSB, was developed as a risk assessment tool for the identification of children under the age of 6 years who may be at risk for ECC, as well as an interactive platform for education and goal setting for ECC prevention. MSB was developed based on an ECC risk assessment model created under the guidance of a multidisciplinary team of health researchers to incorporate risk factors at multiple levels of influence, including individual, family, environmental, and society level influences (Appendix J – MSB Risk Assessment Model).

The multidisciplinary team was composed of professionals from seven Columbia University institutions (schools of medicine, dentistry, nursing, public health, social work, Teachers College, and Center for New Media Teaching and Learning). The project team members included leaders in the fields of behavioral nutrition, community pediatrics, public health, pediatric dentistry, social work, health education, informatics, information technology, diabetes education, peer counseling and policy research. This diverse collection of health professionals allowed for interdisciplinary collaboration in the creation and development of MSB. Each member of the MSB project team brought a specialized set of skills and knowledge to inform the development of this comprehensive ECC risk assessment and educational tool.

The team's expertise and experience in behavioral theory-based research allowed for the incorporation of several known theory-based determinants of health behaviors into the MSB tool. It is widely recognized that use of behavior change theories enhances the effectiveness of health interventions (Spahn et al., 2010). Application of a theoretical basis in the development of health behavior change interventions provides a framework and rationale for selection of appropriate strategies for eliciting behavior change (Spahn et al., 2010). Behavioral theories assist in the identification of internal and external determinants of behavior and help clarify the dynamic interactions between them. Moreover, utilization of a behavior change theoretical framework allows for the individualization of behavioral interventions so they may be tailored to the needs of the individual, accounting for varying degrees of motivation, confidence, environmental support, and skills (Spahn et al., 2010). The team that created MSB utilized several key determinants of behavior change from recognized behavior change theories to direct the development of this comprehensive assessment and educational tool. In order to lay the groundwork for the MSB tool, and root its development in behavioral theories, the team created a novel conceptual model for ECC (Appendix K – MSB Conceptual Model for ECC). The conceptual model proposes various pathways and key constructs, from a number of behavior change theories, that are believed to influence ECC-related behaviors and outcomes.

Consequently, MSB was developed on a foundation of key constructs from the health belief model, theory of planned behavior, theory of reasoned action, trans-theoretical/stages of change model, and social theories of behavior change (B. Edelstein, 2009-2011). Based on these theoretical models of behavior change, MSB was designed to incorporate the evaluation of psychosocial determinants (e.g., health belief, locus of control, self-efficacy, and self regulation), knowledge determinants (e.g., understanding caries pathogenesis, caries control, the roles of diet and fluoride in caries management/prevention), logistic determinants (e.g., family organization and child care arrangements that may serve as barriers or facilitators of change), social and cultural determinants (e.g., social norms and expectations), and environmental determinants of the built environment (e.g., availability of healthy foods/beverages and oral dentifrices) (B. Edelstein, 2009-2011).

The inclusion of these key theoretical constructs permits the individual administering MSB to follow a systematic approach to evaluating family capacity for behavior change, and to design a tailored approach to providing appropriate education and individualized behavior change guidance. Through a series of five assessment modules (diet, feeding practices, thoughts and feelings, fluoride, and family history) containing a sequence of targeted questions, MSB guides the practitioner in recognizing an individual's readiness for change, specific needs and ability to engage in targeted changes (Appendix G – MSB Risk Assessment Modules/Questions). MSB then assists in the identification of targeted goals for eliciting behavior change (also allowing for modification to identified goals over time) to increase the likelihood of engagement in successful behavior change.

2.9.2 – Diet risk assessment. Currently, the AAPD guidelines on caries risk assessment identifies dietary risk based only the number of reported between-meal exposures to sugars-containing foods/beverages, and exposures to sugars-containing bottles (American Academy of Pediatric Dentistry, 2011/2012). However, it has been well established that the overall cariogenicity of the diet is based on numerous additional factors, as previously outlined. Therefore, a more comprehensive system of assessment should be utilized to capture these cariogenicity factors. MSB was designed to address the complex nature of dietary cariogenicity by incorporating information on food cariogenicity from a food scoring method based on timing, physical form, and retention characteristics developed (Palmer Classification of Cariogenicity) with information obtained via expert committee (Appendix F – MSB Food/Beverage Categories and Cariogenicity) (C.A. Palmer, et al., 2010; Levine et al., 2012; Papas et al., 1989).

MSB incorporates this information about food cariogenicity into a modified 24-hour dietary recall module. The dietary recall module was designed to be administered in a similar manner to a traditional 24-hour dietary recall, where participants are prompted to recall and state all foods and beverages consumed over the preceding 24 hours. However, in contrast to a traditional dietary recall, the MSB dietary recall module does not collect data on portion sizes or preparation methods, and does incorporates a collection of commonly consumed food and beverage images that participants are asked to select and identify as being consumed along a 24-hour timeline. MSB was developed specifically for a low-income, predominantly Hispanic population in northern Manhattan, so foods and beverages included in the assessment program were chosen based on focus groups from the target population to ensure appropriateness. A total of 25 food and 7 beverage categories were included to represent the typical diets consumed by this population (Levine et al., 2012). Images for all food and beverage categories were obtained by photographing popular brands available within the target community (Levine et al., 2012).

Each of the food and beverage categories were assigned a weight within the MSB tool, from zero to four, based on estimated cariogenicity (Levine et al., 2012). The cariogenicity weight for each food/beverage category was based on a scoring system called the Palmer Classification of Cariogenicity, which was developed at the Tufts University School of Dental Medicine (Palmer, et al., 2010). This scoring system was designed to include key characteristics of foods associated with caries risk (e.g., physical form and oral retentiveness) (Levine et al., 2012; Palmer, et al., 2010). Cariogenicity weights were also estimated for several of the food/beverage categories included in MSB, for which cariogenicity scores from the Palmer tool were unavailable. For those food/beverage items, the MSB development team included weights based on educated estimates of cariogenicity.

Consuming foods/beverages in combination alters the cariogenicity of the total intake occurrence; whereby lower cariogenic foods consumed with higher cariogenic foods can help buffer the cariogenicity of the latter. Therefore, for foods/beverages consumed in combination, MSB computes an average of the weighted cariogenicity scores. This approach also helps account for the beneficial effect of increased salivary flow during meals, which helps to expedite oral clearance and reduces potential for prolonged demineralization (Mobley, 2003; Sanders, 2004; Touger-Decker & van Loveren, 2003). If the averaged weighted score is greater than or equal to 3, it is considered to be a “risky” eating occurrence. For example, a child who ate a lunch consisting of a peanut butter and jelly sandwich (score = 4), chocolate milk (score = 3), and raisins (score = 4) would receive an averaged score of 3.7 for the meal. Since the score is greater than 3 it would be considered a *risky* occurrence. The total number of these *risky* occurrences is then summed for the day and assigned a combined weight which contributes to a child's dietary risk score (Levine et al., 2012). MSB assigns an overall diet risk score of 0 (*low*), 1 (*moderate*), 6 (*high*), or 9 (*very high*). These scores are based on the following classification criteria: 0 *risky* occasions = 0 risk score; 1-2 *risky* occasions = risk score 1; and 3-4 *risky* occasions = risk score 6; 5 or more *risky* occasions = risk score 9.

2.9.3 – Comprehensive risk evaluation. In addition to the dietary risk score, children assessed with the MSB tool are given risk scores based on answers to a series of questions in four additional assessment modules (Appendix G – MSB Risk Assessment Modules/Questions). Throughout these modules, MSB assigns risk scores based on responses to questions regarding fluoride exposure (e.g., type of toothpaste used), family history data (e.g., parental experience with tooth decay), feeding practices (e.g., use of sippy cups), and thoughts and feelings regarding oral health (e.g., confidence in reducing tooth decay) (Levine et al., 2012). Each response to these questions is assigned a risk score based on estimated importance in identifying caries risk (ranging from 0-9). A multiplier is then applied to the sum total of responses to questions in each module. Those modules deemed most influential in determining caries risk have a higher multiplier (e.g., the diet module has a multiplier of 2; the total score of the diet module is doubled and then added to the total scores for the remaining modules). MSB then calculates a comprehensive ECC risk score (ranging from 1-10), incorporating each of these risk assessment elements with the diet risk score (Appendix H – MSB Weighting Tool).

2.9.4 – Education and goal setting. Upon completion of the assessment modules, MSB then provides the parent/primary caregiver with their comprehensive risk score and an opportunity to review the components of the assessment tool that contributed to their child's risk score. MSB provides an overview of the assessment tool modules and identifies those sections that were scored as high risk, thus providing targeted and individualized feedback regarding patient risk. MSB then provides an opportunity for the parent/primary caregiver to set and record a behavioral goal to assist in reducing their child's risk of caries. MSB was also designed to provide electronic and printable educational resources and goal reminders to parents/primary caregivers upon completion of the assessment. In addition to the resources in the printable library, MSB includes a series of educational videos to provide both "why to" and "how to" knowledge to parents to assist in engaging in desired behaviors. Several videos are available via iTunes, and include an introductory video to MSB, a video on tooth brushing for young children, and video about reducing sugary beverages.

Unlike previously developed ECC risk assessment tools, MSB was designed to act as a standalone, comprehensive, individualized assessment tool addressing multiple levels of influence related to caries risk. Additionally, MSB is quite unique as a risk assessment tool in that it provides an interactive platform for assessment as well as education. The information processed by the MSB tool provides targeted, individualized data which the practitioner may use to develop a patient-specific treatment and prevention plan. The design of MSB and incorporation of individualized information allows it to be utilized multiple times over the course of a child's dental treatment plan. Practitioners may use MSB to reassess risk at recall visits and to follow-up on achievement of behavioral goals to reduce caries risk. The predictive utility of

MSB has yet to be fully tested, but the comprehensive nature of the tool suggests that it may prove to be more predictive of caries risk than existing assessment tools.

2.10 - Study Rationale

The DECC study was conducted as an evaluation and validation of the MSB ECC risk assessment tool, specifically the modified 24-hour dietary recall module. A major component of both primary and secondary prevention of ECC is early detection efforts, such as screening methods and risk assessment tools to identify individuals at highest risk. However, as previously noted, there are no ECC risk assessment tools, to date, that can ensure accurate categorization of children by risk or predict future caries experience through clinical application (Pediatric Oral Health Research and Policy Center, 2012).

MSB holds the potential to fill the current void in effective ECC risk assessment to promote the management and reduction of this devastating infectious oral disease of children. Early identification of risk and prompt, targeted intervention is essential to overcoming the rising rates of ECC. Previously developed ECC risk assessment tools have failed to accurately evaluate the contribution of diet-related behaviors on ECC risk, despite the preponderance of data proving the integral role of diet on ECC development and progression. Findings from the DECC study could establish concurrent criterion validity of this novel risk assessment tool, thus holding the key to finally implementing the comprehensive, non-invasive, reproducible, potentially inexpensive, valid method of assessing susceptibility to future dental caries as outlined by the APPD, that is much needed to combat the growing epidemic of ECC (Pediatric Oral Health

Research and Policy Center, 2012). Utilization of early risk assessment methods to identify children at highest risk of ECC and initiation of preventive oral health treatments are measures that hold the potential to drastically reduce future costs associated with this devastating chronic disease of childhood (Berg & Stapleton, 2012).

Findings from the DECC study will also contribute to the current body of literature on the utility of MS saliva testing among young children. Additionally, the relationship between anthropometric measures (BMI/age percentiles) and dental caries will be further explored within the study population. Moreover, findings from the DECC study will contribute to the growing body of literature on specific dietary intake patterns and food cariogenicity as they relate to caries risk in young children, and may inform the development of future editions of the MSB risk assessment tool.

CHAPTER 3

Methods

This chapter provides a detailed description of the research methods that were employed in the Diet and Early Childhood Caries (DECC) study. These include the study design, setting and participants, the MSB intervention, data collection procedures, and data analysis plan.

3.1 – Overview of Study and Study Design

The DECC study is a cross–sectional study. It is ancillary to a larger study, Bio-Behavioral Chronic Disease Management by Families of Young Minority Children, which created a computer-based ECC risk assessment tool for a portable electronic device (iPad) entitled MySmileBuddy (MSB). MSB was developed to be used as a tool for the identification of children under the age of 6 years who may be at risk for Early Childhood Caries (ECC), as well as to provide an interactive platform for education and goal setting for ECC prevention. Over 100 parent/child (primary caregiver/child) dyads were recruited from a pediatric dental clinic to complete MSB. A variety of physical indicators of caries risk (oral mutans, visible plaque, decalcification, and current ECC status) were assessed during a routine dental examination that all children received. The goal of the DECC study was to establish criterion validity of the MSB tool by concurrently examining the association between various diet-related components of MSB and physical evidence of caries risk. Additionally, the DECC study sought to investigate additional caries-related risk factors, not currently included in the MSB tool, for their potential associations with physical indicators of caries risk. Lastly, an aim of the DECC study was to evaluate the effect of the MSB intervention on self-reported behavior change one month post-intervention. All data were collected between August 2012 and January 2013. Data collection for the one-month telephone follow-up portion of the study took place September 2012 through February 2013.

3.1.1 – Research Questions and Hypotheses

1. Using the MSB risk assessment tool, is there an association between reported food and beverage intake and physical evidence of ECC risk (specifically oral mutans levels, visible plaque, decalcifications and ECC status)?

   a. As measured by frequency (number of exposures) of food and beverage intake occurrences and physical evidence of ECC risk.

   Hypothesis: Children with a higher reported frequency of food and beverage intake will have greater physical evidence of caries risk compared to children with a lower reported frequency of food and beverage intake.

   b. As measured by type of food and beverage categories and physical evidence of ECC risk.

   Hypothesis: Children consuming higher frequencies of food and beverages in the low cariogenic risk categories (e.g., nuts, milk, cheese, meats, starchy vegetables, unsweetened grain products, fruit) will have less physical evidence of caries risk compared to children consuming lower frequencies of these foods and beverages. Similarly, children consuming higher frequencies of food and beverages in the high cariogenic risk categories (e.g., flavored milk, candies, salty snack foods, sweetened cereals, sugared beverages) will have greater physical evidence of caries risk compared to children consuming lower frequencies of these foods and beverages.

2. Using the MSB risk assessment tool, is there an association between the calculated risk scores (diet and comprehensive) with physical evidence of caries risk?

Hypothesis: Children with higher calculated MSB risk scores will have greater physical evidence of caries risk compared to children with a lower calculated diet risk score.

3. Is there an association between reported length of eating or drinking occurrence and physical evidence of caries risk?

a. As measured by a single question (*Is your child a quick eater/drinker or a slow eater/drinker?).*

Hypothesis: Children that are reported to be slow eaters/drinkers will have greater physical evidence of caries risk compared to children reported to be quick eaters/drinkers.

b. As measured by time captured before and after meals/snacks based on a one-day food record in a subset of the sample.

Hypothesis: Children with lower total average minutes spent eating or drinking throughout the day will have less physical evidence of caries risk compared to those with higher total average minutes.

4. Is there an association between body mass index-for-age (BMI/age) percentiles and physical evidence of caries risk?

   Hypothesis: Children with BMI/age percentiles at the extremes (below the 5th or above the 95th percentile) with have greater physical evidence of caries risk compared to those with BMI/age percentiles within a healthy range.

5. Is there an effect of the MSB intervention, as measured by self-reported behavior change, at one month post-intervention?

   Hypothesis: Parents who recall MSB behavior change goals at one month post-intervention will report engaging in targeted ECC-related behavior changes.

3.2 – Informed consent

Permission was granted for the conduct of the DECC study by the Institutional Review Board (IRB) Teachers College Columbia University (Protocol: 13-158) as well as the Columbia University Medical College IRB (Protocol: IRB-AAAJ7158). Informed consent was obtained in person by one of the four DECC study researchers (CLC, DK, AL, GT) for each participant recruited. Participants signed a HIPAA form, which granted permission for the researchers to review protected health information. Due to the young age of the children participating in the DECC study, none were capable of providing assent. Therefore, parents/primary caregivers provided consent on their behalf.

Informed consent and HIPAA forms were completed in the preferred language of the parent/primary caregiver participating in the project, either in English or Spanish. All forms and printed materials for the DECC study were also provided in the preferred language of participants. All four members of the research team who conducted participant interviews and assisted with data collection were bilingual (English and Spanish).

3.3 - Study Setting

The DECC study was conducted at the Columbia College of Dental Medicine Pediatric Dentistry Clinic. The clinic is located in the northern part of the New York City borough of Manhattan, within the Washington Heights neighborhood. The clinic primarily serves patients from three surrounding communities with fluoridated water (Harlem, Washington Heights and Inwood), which have predominantly low-income and Hispanic populations (Yoon et al., 2012). The majority of families receiving care at the clinic prefer to use Spanish as their primary language.

3.4 - Study Participants

3.4.1 – Sample. The goal was to recruit a convenience sample of approximately 100 parent/child dyads (or primary caregiver/child dyads) for participation in the DECC study. This sample size was chosen based on samples recruited in previous studies investigating relationships between diet and caries risk. Additionally, it was believed that recruitment of this sample size would be both practical and feasible within the dental clinic setting. The parents/caregivers recruited for the DECC study were adults over the age of 18 years. The target age range for children participating in the study was between 2 and 6 years, as this is the appropriate age range during which evidence of ECC is present. The parent/child (or primary caregiver/child) dyads recruited were individuals presenting to the Columbia College of Dental Medicine Pediatric Dentistry Clinic on Mondays, Tuesdays and Wednesdays for routine dental examinations. Routine examinations were a combination of new patient and follow-up examinations conducted by an attending pediatric dentist, a pediatric dental resident or a dental hygienist. Children with and without ECC were anticipated to be observed within this population.

3.4.2 – Recruitment procedures. Participants were individually recruited from the waiting room and examination rooms of the Columbia College of Dental Medicine Pediatric Dentistry Clinic. Recruitment occurred while parents/caregivers were awaiting routine dental examinations for their children. Members of the DECC study research team actively engaged parents/caregivers to recruit potential participants from the pool of individuals presenting to the clinic for non-urgent pediatric dental care. The investigators individually identified and approached potential participants who fulfilled the participant inclusion criteria (parents/primary caregivers over the age of 18 with healthy children 2 to 6 years of age). The clinic staff, when able, also assisted investigators in the identification of potential participants in the waiting room and examination areas of the clinic and informed the clinic patients of the opportunity to participate in the DECC study.

Recruitment flyers were posted in the clinic waiting room and were distributed directly to clinic patients to inform parents/caregivers of the opportunity to participate in the study

(Appendix I - Recruitment Flyer). The flyers included a basic description of the study purpose and activity, and instructed the potential participant to ask the clinic staff for additional information if interested. For those interested, staff explained the study and obtained consent. A Metrocard ($10 value) was offered to participants as a small token of appreciation for their participation in the DECC study.

3.4.3 – Inclusion/exclusion criteria. Recruitment for the DECC study was limited to parent/caregivers and their children between 2-6 years of age. Children with a medical condition or developmental disability that holds the potential to impact diet and oral health were excluded from recruitment in the study (e.g., Cerebral Palsy). Additionally, children below 2 years and above 6 years of age were excluded. Therefore, only children between the ages of 2 years (when full dentition is achieved) and 6 years (the age limit for being qualified at-risk for ECC) were considered for participation in the DECC study. When parents/caregivers presented with more than one child within the target age range, the youngest child was chosen for participation.

Additionally, since the potential existed for parents/primary caregivers of children to be minors themselves, recruitment was limited to only those parents/primary caregivers who were adults, over the age of 18 years, competent to consent.

3.5 – Data Collection

After the oral examination and completion of informed consent for participation, the MSB tool was administered by a research investigator (CLC, DK, AL, and GT). The oral examination and mutans testing took place within a private examination room at the clinic. The dental provider recorded the clinical examination findings in the electronic medical record. Once the clinical examination was complete, a member of the DECC study research team took height and weight measurements of the child.

Completion of the MSB assessment took approximately 15 to 20 minutes. MSB was completed primarily within a private conference room at the clinic and, on occasion, within the examination and waiting room areas. During this time, the researcher interviewed the parent/caregiver, and offered children the opportunity to play with various toys that were made available for their use.

Upon completion of the MSB assessment, or at the end of the day, the researcher reviewed the medical record with clinic staff for relevant information from the clinical examination. The MSB assessment was therefore conducted by the researcher prior to their knowledge of the oral examination findings. It should be noted that only information regarding patient medical record number, age, telephone number, and results/findings of the oral examination and MS test were reviewed; no additional information was collected from the dental records (Appendix P – Data Collection Forms). Two days after the collection of the oral mutans sample, the researcher returned to evaluate and score the results of the oral mutans test.

3.6 – MySmileBuddy (MSB)

The DECC study utilized the MSB risk assessment tool designed for a portable electronic device (iPad), which was developed under a previous study entitled Bio-Behavioral Chronic

Disease Management by Families of Young Minority Children. MSB is a theory-based tool that was created as a means of identifying children under the age of 6 years who may be at risk for ECC, and was designed as an interactive platform for education and goal setting to promote ECC prevention. The MSB tool consists of a series of questions, similar to a survey/questionnaire, a modified 24-hour dietary recall module, and brief educational modules related to ECC risk. The MSB tool was developed specifically for the low-income, minority, primarily Hispanic, population served by the Columbia College of Dental Medicine Pediatric Dentistry Clinic in northern Manhattan.

A primary component of MSB is the behavioral risk assessment module, which includes a modified 24-hour dietary recall component. The modified dietary recall was designed to be administered in a similar manner to a traditional 24-hour dietary recall, where participants are prompted to recall and state all foods and beverages consumed over the preceding 24 hours. In contrast to a traditional dietary recall, the MSB dietary recall module does not collect information regarding portion sizes and preparation methods, as these are not of high relevance in the assessment of caries risk. The MSB dietary recall module was designed to provide visual cues to assist in dietary data collection, incorporating a collection of commonly consumed food and beverage photographs that participants are asked to select and identify as having been consumed along a 24-hour timeline (Appendix E - MSB Screenshots).

While completing the MSB assessment, participants were provided with information about how tooth decay develops and how they may decrease their child's risk of dental caries. The data collected from the MSB assessment tool included information about parental knowledge, beliefs, attitude, experience, and behaviors related to their child's oral health, diet and risk of ECC. These data provided an overall assessment of ECC risk, incorporating risk scores from each area of data collected. The MSB assessment tool recorded all responses and assigned corresponding risk scores based on a weighting algorithm built into the analysis software (Appendix H – MSB Weighting Tool). Each of the questions from the five MSB assessment modules (diet, feeding practices, thoughts and feelings, fluoride, and family history) were assigned weights based on prior literature on cariogenic potential as well as clinical expertise and automatically scored by MSB (Appendix G – MSB Risk Assessment Modules/Questions).

Upon completion of the questionnaire portion of MSB, a comprehensive ECC risk score based on available data was revealed to participants. MSB made suggestions to participants for areas they may want to try to improve with their child based on their risk score. MSB then prompted participants to identify one or two targeted behavior change goals to reduce their child's risk of ECC. For additional details on the development and content of MSB, see chapter 2, section 2.9 – Development of MySmileBuddy. All data regarding specific goals, steps to assist in achievement of stated goals, responsible individual, and time frame during which goals were to be reach were recorded in the MSB program.

3.7 – Measures

The primary measures of interest in the DECC study included various components of the MSB risk assessment tool, oral examination findings, average oral exposure time, anthropometrics, and self-reported behavior change one-month after the MSB intervention

(Table 3.1 – Overview of DECC Study Measures). Measures collected via MSB were used in conjunction with oral examination findings to establish criterion validity of the MSB tool, and included dietary intake patterns (frequency and type of foods/beverages consumed), calculated MSB *diet* and *comprehensive* risk scores, reported length of intake occurrences (eating/drinking pace), and demographic information. Oral exposure time was also measured with a one-day food record in a subset of the sample. Measures related to oral examination findings included oral MS colonization levels, level of visible plaque, presence of decalcification, and ECC status. Anthropometrics included weight and height measurements. Self-reported behavior change included recollection of MSB goals and attempts to change behavior.

Table 3.1

Overview of DECC Study Measures

Evaluation Method	Measures
MySmileBuddy (MSB)	MSB Diet Risk Score MSB Comprehensive Risk Score Intake Patterns: Frequency and Type of Food/Beverage Categories Consumed, Frequency of Meals/Snacks/Beverages Oral Exposure Time: Quick/Slow Eater/Drinker Question Demographics: Sex, Age, Race/Ethnicity, Preferred Language, Parent/ Caregiver Immigration Status and Educational Achievement, Receipt of WIC/Food Stamp Assistance, Insurance Coverage
One-Day Food Record	Oral Exposure Time: Length of Intake Occurrences
Anthropometrics	Height, Weight, BMI/Age Percentile, Weight Status
Oral Examination	Oral Mutans Level Visible Plaque Level Presence of Decalcification ECC Status
One-Month Follow-Up Survey	Recollection of MSB and Goals Behavior Change Attempts

Note. Only data collected via MSB and oral examination measures were used to establish criterion validity of the MSB tool; food record, anthropometric, and one-month follow-up survey data was not included in MSB validation.

3.7.1 – Frequency and type of food/beverage categories consumed. The modified 24-hour dietary recall component of the MSB tool provided data on consumption of 32 food and beverage categories (25 food and 7 beverage categories). Details from the 24-hour recall were extracted in order to specifically evaluate which food/beverage categories were consumed by each participant, as well as how many times during the previous day items from those categories were consumed. This data was also used to evaluate the number of meals, snacks, and beverages consumed during the previous day. The MSB tool allows for the designation of intake occurrences as *meals* or *snacks*; however, this data was not consistently collected in the DECC study. Therefore, evaluation of intake occurrence type was conducted by the principal investigator on the DECC study (CLC), and subjectively coded as either a *meal, snack,* or beverage (not including water/plain seltzer) intake occurrence. Moreover, data extracted from the modified 24-hour recall allowed for analysis of intake by food/beverage category cariogenicity (Appendix F – MSB Food/Beverage Categories and Cariogenicity). The Evaluation of consumption data for both food/beverage categories as well as cariogenicity groups allowed for the investigation of relationships between type of intake and physical evidence of caries risk.

3.7.2 – MSB diet risk score. A diet risk assessment score was calculated for each participant by incorporating reported intake data from the MSB 24-hour recall module with the aforementioned food/beverage category cariogenicity (Appendix F – MSB Food/Beverage Categories and Cariogenicity). A unique feature of MSB diet assessment tool was that it was designed to average the estimated cariogenicity of each food/beverage category consumed during each reported intake occurrence. This approach is believed to help account for the decreased cariogenicity of foods consumed in combination due to the buffering effect of low cariogenic foods/beverages and the increases salivary excretion during meals (Mobley, 2003; Sanders, 2004; Touger-Decker & van Loveren, 2003). For example, a child who ate a lunch consisting of a peanut butter and jelly sandwich (score = 4), chocolate milk (score = 3), and raisins (score = 4) would receive an averaged score of 3.7 for the meal. Since the score is greater than 3 it would be considered a *risky* occurrence. Each intake occurrence that receives an averaged cariogenicity weight equal to or above 3 is considered a "risky" occurrence. The total number of occurrences classified as *risky* were summed for the day and each participant was assigned a corresponding diet score. The diet risk score generated by MSB categorized participants based on calculated risk score as 0 (*low*), 1 (*moderate*), 6 (*high*), or 9 (*very high*). These scores were based on the following classification criteria: 0 *risky* occasions = risk score 0; 1-2 *risky* occasions = risk score 1; and 3-4 *risky* occasions = risk score 6; 5 or more *risky* occasions = risk score 9. In order to establish criterion validity of the MSB risk assessment tool the MSB diet risk score and physical evidence of caries risk were concurrently evaluated to investigate the existence of associations among these variables.

3.7.3 – Comprehensive MSB risk score. The diet risk assessment score calculated by MSB was ultimately incorporated into the calculation of a comprehensive MSB risk score. The comprehensive MSB risk score was composed of weighted scores from multiple MSB risk assessment modules and incorporated answers to specific questions regarding feeding practices (e.g., How often do you pre-chew your child's food?), thoughts and feelings (e.g., How confident are you in reducing your child's risk for tooth decay?), fluoride use (e.g., What type of toothpaste does your child most routinely use?), and family history (e.g., Have you (parent or caregiver) ever had an abscessed tooth?) (Appendix G – MSB Risk Assessment Modules/Questions). Much like the diet risk assessment score, the comprehensive MSB risk score was utilized in the evaluation of potential associations with physical indicators of ECC risk as a means of establishing concurrent criterion validity for the MSB tool.

3.7.4 – Length of intake occurrences. In order to assess the relationship between oral exposure time and physical evidence of caries risk, reported length of eating/drinking pace was evaluated. This measure was assessed by both a single question incorporated into MSB as well as evaluation of a paper-based one-day food record (for a subset of the population).

Quick/slow eater/drinker question. In order to evaluate typical eating/drinking pace, parents/primary caregivers were asked a simple question, "Is your child a quick eater/drinker or a slow eater/drinker?" This question was incorporated in the MSB tool as a concise method of assessing typical intake pace for the purposes of the DECC study; however, it did not contribute to the calculation of the diet or comprehensive MSB scores. The response to this question was intended to be a proxy for direct collection of oral exposure time data. Investigation into the utility of this question was included as a component of the DECC study as a means of determining if it would be worthwhile to include in a future edition of the MSB tool; this was not included in the current validation of MSB.

One-day food record. A subset of the population was asked to provide additional data in the form of a paper-based food record (Appendix L – One-Day Food Record). All participants were offered the opportunity to participate in this portion of the project. Those who agreed were instructed to record all foods/beverages consumed by their child, at both the beginning and end of each eating/drinking occurrence for a one-day period. The food records were designed to collect start/end times of food/beverage intake occurrences to allow for the calculation of the duration of each eating/drinking occurrence as well as total oral exposure time throughout the day. Participants were instructed to return the completed food record, in a self-addressed stamped envelope that was provided at time of recruitment, to the research team. Upon receipt of the completed food record, participants were then mailed a Metrocard ($10 value) in appreciation for their participation. All food records were reviewed upon receipt for proper completion. For those participants who completed food records incorrectly or insufficiently, they were asked during the one-month telephone follow-up call if they were interested in completing another food record. If they agreed to resubmit the food record, they were instructed on proper completion procedures and promptly mailed a new food record with self-addressed, stamped, return envelope. The data collected from the food record was intended to serve as a detailed account of oral exposure time for evaluation against physical indicators of caries risk, and to potentially validate the quick/slow eater/drinker question; oral exposure time was not included in the validation of the MSB tool.

3.7.5 – Visible plaque, decalcification, and ECC status. The oral examination procedures provided data on physical findings associated with caries risk. The physical assessment risk factors collected during the oral examination included data on presence of frank cavitations and associated precursors to the caries process (namely, plaque and decalcification). The oral examination was conducted using the “knee-to-knee” approach, whereby the child was held in the parent/caregiver’s lap, and the dentist visualized teeth with the use of a focused light and hand-held mirror.

Level of visible plaque was assessed using a modified version of the Loe plaque index criteria utilized at the clinic (Silness & Loe, 1964). In order to evaluate presence of decalcification and frank cavitations, the clinic staff based evaluations on the World Health Organization's "Dentition Status and Treatment Needs" protocol (B. Edelstein, 2009-2011). As per clinic protocol, all dental residents were trained in plaque scoring and identification of decalcifications during the first two months of their residency program through seminars and written materials. Furthermore, examiner reliability testing is routinely done every day at the clinic with the attending faculty, to ensure consistency in evaluation of clinical measures.

Because previous caries experience is a significant predictor of future caries experience, decayed/ filled primary teeth (dft) index and decayed/ filled primary surface (dfs) index values were determined for each child participating in the DECC study. The contributing physical indictors used in the calculation of dft/dfs indices includes cavities, arrested caries, and filled cavities; evidence of tooth decay and previous restorations. A table outlining the presence of dft/dfs index scores of DECC participants, along with data on each of the factors that contribute these indices may be found in Appendix N– DECC Participant Caries Experience. The dfs index was then used to identify children who met the diagnostic criteria for ECC or S-ECC, as defined by the American Academy of Pediatric Dentistry (AAPD). The AAPD defines ECC as the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries) or filled tooth surfaces in any primary tooth in a preschool-aged child between birth and 71 months of age (American Academy of Pediatric Dentistry, 2011). In children younger than 3 years of age, any sign of smooth-surface caries is indicative of S-ECC; from ages 3 through 5 years, 1 or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth or a decayed, missing, or filled score of ≥ 4 (age 3), ≥ 5 (age 4), or ≥ 6 (age 5) surfaces also constitutes S-ECC (American Academy of Pediatric Dentistry, 2008; Drury et al., 1999).

3.7.6 – Mutans streptococci (MS). Saliva samples were taken from all participating children as part of their oral examination. The MS saliva test that was conducted during the oral examination provided data on approximate levels of MS present in the saliva, as a measure of caries risk associated with bacterial counts. After collection of saliva, agar MS testing plates were inoculated and prepared for incubation. The oral MS testing procedure included collection and analysis of a small amount of saliva, and followed the same collection protocol as previously conducted research at the clinic (Yoon et al., 2012). To assess MS levels, a small amount of unstimulated saliva was collected by pressing a sterile tongue depressor onto the dorsal surface of the patient's tongue and then impressing the tongue depressor onto an MS-selective agar medium (mitis salivarius, kanamycin, bacitracin agar, Fisher Scientific, Pittsburgh).

MS agar plates were then incubated for 48 hours at 98.6°F in a countertop incubator (Complete Culture Control Incubator, Model 132000, Boekel Scientific, Troy, Mich.) after they had been placed inside a tightly sealed plastic bag inflated with air exhaled by one of the researchers to establish a partially anaerobic environment. Following the 48 hour incubation period, the principal investigator (CLC) evaluated each agar plate to determine the number of characteristic colony-forming units (CFUs) present and categorized the MS level for each plate as low (no detectable CFUs), moderate (1 to 50 CFUs), high (51 to 100 CFUs) or very high/too numerous to count (more than 100 CFUs) (Yoon et al., 2012).

3.7.7 – Body mass index for age (BMI/age) percentile. Anthropometric measures were taken on all children as part of their comprehensive examination. A member of the research team collected data on height and weight measurements using the scale available at the clinic with built-in stadiometer (Detecto Weigh Beam Eye-Level Scale). Children were instructed to remove any heavy outerwear (i.e., winter coat) and were weighed and measured with all other clothing, including sneakers/shoes; as footwear and light clothing would likely only contribute a nominal amount to weight/height measures. All members of the research team were trained to ensure consistency of anthropometric measurement techniques.

The anthropometric measures collected were then used in conjunction with participant age (calculated from date of birth to date of study recruitment) for the purpose of calculating BMI/Age percentiles. An Excel-based BMI/Age calculator created by the Centers for Disease Control and Prevention (CDC) was used to calculate precise values for BMI/Age percentiles for each participant (Centers for Disease Control and Prevention, 2010). Calculated BMI/Age percentiles were then used to classify participants according to each of the four recognized pediatric weight status categories defined by the CDC: Underweight (< 5^{th} percentile); Healthy Weight (5^{th} to < 85^{th} percentile); Overweight (85^{th} to < 95^{th} percentile; Obese ≥95^{th} percentile) (Centers for Disease Control and Prevention, 2011). BMI/age percentiles and weight status categorization was included in the DECC study measures in order to investigate potential associations with physical indicators of caries risk; this information was not included in the validation of the MSB tool.

3.7.8 – Recollection of MSB goals and self-reported behavior change. All participants were contacted via telephone approximately one month after completing the MSB iPad application. Researchers collected telephone contact information (and alternative contact numbers) at time of recruitment into the DECC study. If participants were not reached upon initial follow-up call, multiple attempts were made to reach participants and messages were left when possible. Attempts to reach participants were made until study close (3/1/13). When participants were reached for follow-up, researchers followed a pre-written telephone script to ensure consistency in follow-up call procedures (Appendix M – One-Month Follow-Up Telephone Script). Participants were asked (yes/no) if they recall setting a behavioral goal via MSB to reduce ECC risk. If yes, participants were asked what the goal they chose to work on was, and if they had done anything to try to achieve their goal. If no, they were reminded of their goal and, once reminded, were asked if they had made any changes to achieve their goal. In addition, all participants were asked if they had made any changes in their child's diet and/or oral health regimen as a result of the information they received during their participation in the study. The follow-up telephone calls took approximately 5 minutes to complete.

3.7.9 – Demographics. Basic demographic information was collected as a component of the MSB tool at the beginning of the assessment. Prior to answering the diet and oral health-related questions in the MSB tool, parents/caregivers were asked to identify the age of the child and the child's race/ethnicity. Additionally, parents/caregivers were asked about the highest level of education they completed, whether or not they were born in the Unites States, and if they participated in the food stamp (now known as Supplemental Nutrition Assistance Program) and Women Infants and Children (WIC) programs during the past year. Parents/caregivers were also asked by DECC study researchers which language they preferred (Spanish/English) for administration of the MSB tool and receipt of study materials. Information on dental insurance coverage was also collected from clinic records. These demographic data were used to describe the sample population, and were also employed in the assessment of correlations with DECC study predictor and outcome variables to control for confounding variables, if necessary.

3.8 – Training

The three research assistants (AL, DK, and GT) and principal investigator (CLC) collecting data were trained to follow a specific series of procedural steps as outlined in a data collection guide created for the DECC study (Appendix O – Data Collection Guide). The three research assistants were students in the Master of Science Program in Nutrition at Teachers College Columbia University. The Training for the DECC study included training on the navigation and use of the MSB risk assessment tool as well as training on appropriate anthropometric measurement techniques and the MS testing protocol.

All research team members practiced MSB interviewing techniques with numerous parents of young children with whom they were acquainted, as well as with other members of the research team. To ensure consistency in administration techniques and data collection procedures, researchers observing administration of the MSB 24-hour recall by the principal investigator simultaneously recorded collection of dietary intake information on separate iPads. The results of their data input were then compared and inconsistencies were reviewed until consensus on food/beverage category selection was reached.

Researcher training on proper techniques for the collection of saliva samples, agar plate preparation and incubation, as well as result interpretation was conducted via hands-on training. Two pediatric dentists at the clinic trained the principal investigator, (CLC) was trained on proper MS testing and result interpretation procedures. All other researchers were trained as well, in the event that the principal investigator was unable to evaluate MS results personally. To ensure that all MS test results were read consistently, training included repeat interpretation of MS test results by the principal investigator on the DECC study (CLC). In an effort to minimize risk of researcher bias, MS test results were interpreted independent of participant identifiers and other participant data. Additionally, members of the research team were trained on proper height and weight measurement techniques so that anthropometric measurements on all children were taken in a systematic and consistent manner.

3.9 - Data Analysis Plan

The DECC study principal investigator (CLC) entered all data collected into a Microsoft Excel database and carefully reviewed data for incorrect or missing values. Outliers were flagged and data were rechecked prior to completion of statistical analyses. Preparation of data for analysis also included review of non-numerical categorical variables. All categorical variables were assigned numeric codes to aid in statistical analysis (Appendix Q – Variable Code Table). The cleaned and coded database was then entered into, and analyzed by IBM SPSS Statistics software, version 21.

Because the DECC study utilized a cross–sectional study design, the study consisted of a single round of data collection, where exposure factors and outcomes were measured concurrently. Therefore, methods for statistical analysis were chosen to examine associations among key variables of interest. The following provides an outline of the key variables evaluated in analysis of DECC study data and the statistical analysis techniques employed.

The primary aim of the DECC study was to validate the modified 24-hour dietary recall module of the MSB risk assessment tool and to identify several diet-related risk factors for caries, including associations between ECC and consumption of specific foods, dietary intake patterns and BMI/age among participants. The data for this study were primarily collected via the MSB application, but also included information on findings from the clinical examination collected from the dental record, bacteriologic samples measuring level of oral MS colonization, the one-day food record, and the one-month follow-up survey.

The MSB risk assessment tool provided data for the key independent variables of interest in the DECC study (risk assessment score, both *diet* and *comprehensive*; food/beverage consumption patterns; intake frequency), while the clinical examination and bacteriologic samples provided data on physical indicators of caries (MS, visible plaque, decalcification, and ECC status). Concurrent evaluation of the MSB variables against physical indicators of caries was conducted in order to establish criterion validity.

Although not a component of the MSB validation, information was also collected at the time of oral examination on anthropometrics (height and weight) to determine BMI/age percentile to evaluate a possible association between caries risk and anthropometrics in the sample population. Associations between anthropometrics and physical indicators of caries were analyzed by both BMI/age percentile and BMI weight status.

Data from the one-day food record permitted evaluation of start/end times of food/beverage intake occurrences to allow for the calculation of the duration of each eating or drinking occurrence; this was also ancillary to validation of the MSB risk assessment tool (Appendix L – One-Day Food Record). Furthermore, the food record provided data for evaluation of food intake patterns. Lastly, data from the one-month follow-up telephone survey provided evaluation of behavioral changes among study participants. The survey data also allowed for determination of participant recollection of stated goals established during MSB administration.

Descriptive methods of analysis were used to provide details on characteristics of the study population, as well as to describe all study variables. Descriptive measures included means (*M*), standard deviations (*SD*), frequencies, and ranges, when appropriate. Descriptive analysis techniques were also applied to the follow-up survey data to describe behavioral outcomes one month post-intervention.

Associations among MSB, anthropometric, physical indicators of caries, and food record data were assessed via Ordinal Logistic Regression (OLR), using the Polytomous Universal Model (PLUM) procedure in SPSS. The OLR method of statistical analysis was chosen because of the nature of the DECC study variables. All four of the main physical indicators of caries that were used as outcome variables in the DECC study are ordinal categorical variables; they are rank ordered, but the ordered categories are not necessarily equidistant. Because of the ordinal nature of the variables, OLR was deemed the most appropriate method of analysis. The OLR method is an extension of the general linear regression model, however, it allows for examination of associations between ordered categorical variables while accounting for their ranked order. Furthermore, OLR allows for the inclusion of potential confounding variables in order to control for their influence on outcome variables.

Although OLR was chosen as the most appropriate method of evaluating relationships with the DECC study ordinal outcome variables, Analysis of Variance (ANOVA) was also used in evaluation of the study data. ANOVA was primarily included in presentation of the DECC study results, for illustrative purposes. The ANOVA procedure provides useful information regarding trends in mean values, which may aid in clarifying how variables relate to one another. Thus, the following chapter includes some data in the form of ANOVA tables in addition to the OLR statistical results.

CHAPTER 4

Results

4.1 – Introduction

This chapter summarizes the findings from the DECC study, an evaluation and validation study of the MSB ECC risk assessment tool. Analysis of study findings is based on data collected via administration of MSB, oral examination findings, MS test results, anthropometrics, one-day food records and one-month follow-up telephone surveys.

4.2 - Study Flow

In total, 113 parent/primary caregivers were approached to participate in the DECC study between August 2012 to January 2013. A total of 108 (95.6%) parent/child dyads (or primary caregiver/child dyads) agreed to participate in the study and were subsequently recruited for participation (Figure 4.1 – DECC Study Flow Chart). The five individuals who declined participation primarily stated time constraints as a reason for declination. All 108 of the recruited participants completed MSB, the oral examination, MS testing, and anthropometrics. All study participants were contacted via telephone approximately one month post-intervention for administration of the follow-up survey. Although attempts were made to contact all 108 participants, 7 participants (6.5%) had incorrect or nonworking telephone numbers, despite collection of primary and secondary (when available) contact numbers at time of recruitment. Additionally, 5 participants (4.6%) declined participation in the follow-up survey, and another 17

(15.7%) were unable to be reached (no response after multiple call attempts). Thus, of the 108 DECC participants recruited, follow-up surveys were successfully completed for 79 participants (73.1%), representing an overall attrition rate of 26.9% for the follow up survey. Comparison of demographic information (i.e., race/ethnicity, immigration status, language preference, mother's educational achievement, and WIC/Food Stamp participation) via Chi-Square analysis did not reveal any statistically significant differences between those participants lost to follow-up and those who completed the one-month follow-up survey (Appendix S – Comparison of Lost-to-Follow-Up and One-Month Survey Completers).

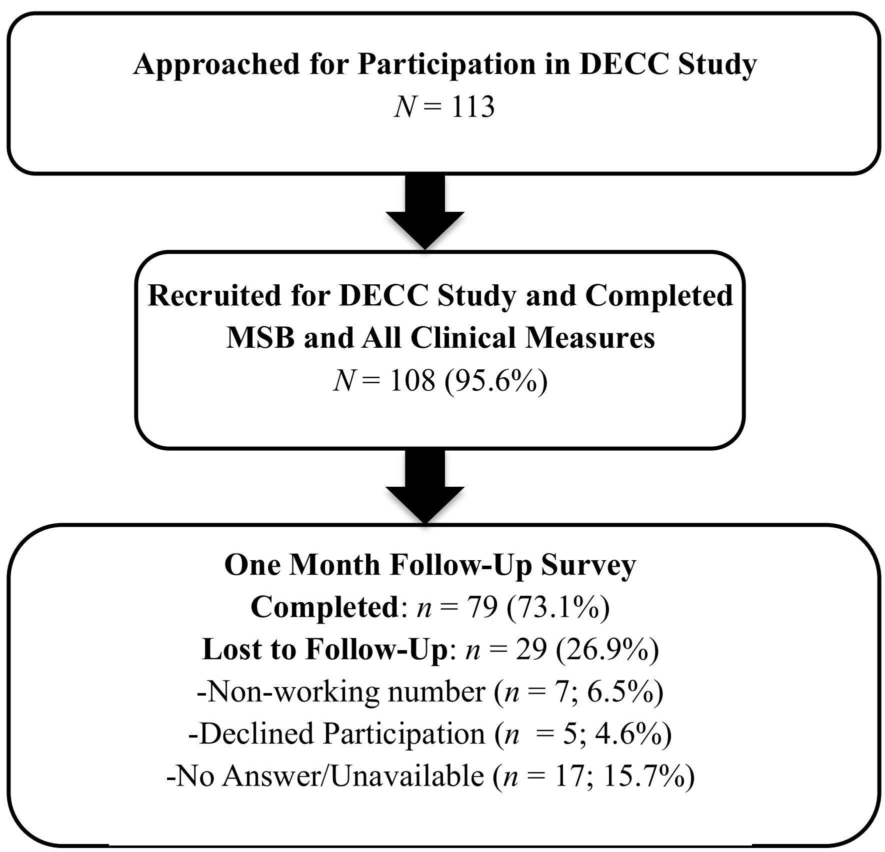

Figure 4.1. DECC Study Flow Chart

4.3 - Characteristics of Sample

Participants recruited for the DECC study were parents/primary caregivers of patients (2-6 years of age) receiving routine care at the Columbia College of Dental Medicine Pediatric Dentistry Clinic. The average age of the children participating in the DECC study was 4.12 years (4.32 and 3.97 years for males and females, respectively). The majority of children were reported by parents/caregivers to be Hispanic (88%). The sex of the children was fairly evenly distributed, with a slight majority being female (56.5%) (Table 4.1 – Demographic Data).

Parents/caregivers recruited for the DECC study were primarily mothers (88.9%), predominantly Spanish speaking (72.2%), and foreign born (75.9%). Data collected (from 92.6% of participants) regarding mother's self-reported highest level of educational achievement, revealed that participants were fairly evenly distributed among the three categories. A slight majority of mothers reported having completed high school (32.4%), while slightly less reported that they did not complete high school (31.5%), and even fewer reported having completed more than high school (28.7%). The majority of participants are posited to be low-income, as indicated by participation in WIC (62%), receipt of food stamps within the past year (70.4%), and utilization of Medicaid insurance coverage (3.7% Medicaid *Only;* 95.4% Medicaid *Plus* Supplementary Insurance).

Table 4.1

Demographic Data

Variable	*n*	(%)
Total Sample	108	(100)
Child's Sex		
Male	47	(43.5)
Female	61	(56.5)
Child's Age (*M* = 4.12 years)		
2	21	(19.4)
3	24	(22.2)
4	31	(28.7)
5	29	(26.9)
6	3	(2.8)
Child's Race/ Ethnicity		
African American	12	(11.1)
Caucasian	1	(0.9)
Hispanic	95	(88.0)
Parent/Caregiver Relationship		
Mother	96	(88.9)
Father	11	(10.2)
Grandparent	1	(0.9)
Parent/Caregiver Immigration Status		
US Born	26	(24.1)
Foreign Born	82	(75.9)
Parent/Caregiver Language Preference		
Spanish	78	(72.2)
English	26	(24.1)
English/Spanish	4	(3.7)
Parent/ Primary Caregiver Educational Achievement		
No Data	8	(7.4)
Did Not Complete High School	34	(31.5)
Completed High School	35	(32.4)
Completed More Than High School	31	(28.7)
Food Stamp Recipient	76	(70.4)
WIC Participant	67	(62.0)
Insurance Coverage		
Medicaid *Only*	4	(3.7)
Medicaid *Plus* Supplementary Coverage	103	(95.4)

4.4 - Reporting Results

4.4.1 – Physical evidence of caries risk. The DECC study collected data on several physical indicators of caries in order to examine potential associations between risk factors evaluated via administration of the MSB tool and established clinical risk factors. The data collected on physical indicators of caries risk consisted of four main categorical variables (oral mutans levels (MS), visible plaque, decalcification, and ECC status) for each child participating in the study. The following section details the results from descriptive analyses on all four physical indicators of caries risk. Analysis of relationships among these physical indicators and DECC study predictor variables will be presented in the corresponding sections that follow.

Oral mutans. Incubated saliva samples were used to determine colonization levels of oral mutans streptococci (MS), which provided ordinal data categorizing MS levels as “Low” (0 CFU), “Moderate” (1-50 CFU), “High” (51-100 CFU), or “Very High” (>100 CFU). All four categories of MS levels were represented within the sample of children participating in the DECC study (Table 4.2 – Physical Indicators of Caries Descriptive Analysis). The majority of children presented with *moderate* levels of oral MS (n = 65; 60.2%), with the next most frequently observed MS levels falling within the *low* category (n = 35; 32.4%). The categories of MS levels with the fewest number of child participants represented were the *high* (n = 5; 4.6%) and *very high* (n = 3; 2.8%) categories.

Visible plaque. Presence of visible plaque was determined during the comprehensive oral examination that each child in the DECC study received. Evidence of visible plaque was evaluated as an ordinal variable categorized as, “None”, “Mild”, “Moderate”, or “Severe” plaque

(Table 4.2 – Physical Indicators of Caries Descriptive Analysis). Nearly half of the child participants presented with *mild* levels of visible plaque (*n* = 50; 46.3%), with the remainder almost evenly distributed between the *moderate* (*n* = 26; 24.1%) and *none* (*n* = 27; 25%) categories. A small number of children were categorized as having *severe* levels of visible plaque (*n* = 5; 4.6%).

Decalcification. Since decalcifications (white spots) are precursors to frank cavitations, presence of decalcification was recorded for each child as a dichotomous variable with a response of, "Yes" or "No" to indicate presence or absence, respectively, of decalcification (Table 4.2 – Physical Indicators of Caries Descriptive Analysis). The data reveal that nearly two thirds of children presented with no evidence of decalcification (*n* = 71; 65.7%), and just over one third did present with evidence of decalcification (*n* = 37; 34.3%).

ECC status. Because previous caries experience is a strong indicator of future caries risk, decayed/filled primary teeth (dft) and decayed/filled primary surface (dfs) indices were calculated for each participant. The dfs index was then used to identify children who met the diagnostic criteria for ECC or S-ECC, as defined by the American Academy of Pediatric Dentistry (AAPD). Children were categorized as presenting with "No ECC", "ECC", or "S-ECC". Nearly half (49%) of the children participating in the DECC study did not meet the diagnostic criteria for ECC and were within the *No ECC* category (Table 4.2 – Physical Indicators of Caries Descriptive Analysis). Of those who met the diagnostic criteria for ECC, the majority were classified as presenting with S-ECC. A total of 41 (38%) of the children in the DECC study met the diagnostic criteria for S-ECC, with 14 (13%) meeting the criteria for ECC.

Table 4.2

Physical Indicators of Caries Descriptive Analysis

Indicator	*n*	(%)
Oral Mutans		
Low	35	(32.4)
Moderate	65	(60.2)
High	5	(4.6)
Very High	3	(2.8)
Visible Plaque		
None	27	(25)
Mild	50	(46.3)
Moderate	26	(24.1)
Severe	5	(4.6)
Decalcifications		
No	71	(65.7)
Yes	37	(34.3)
ECC Status		
No ECC	53	(49)
ECC	14	(13)
S-ECC	41	(38)

Correlation analysis of physical indicators. In addition to descriptive analysis of these physical indicators of caries risk, further analyses were performed to explore inter-variable associations and to investigate potential relationships among demographic variables.

Inter-variable associations. The Chi-Square analysis procedure was used to investigate the relationships between each of the DECC study outcome variables. Chi-Square analysis confirmed that the majority of the physical indicators of caries risk were associated with one another, although not all were statistically significant. This finding is not surprising, as all outcome variables were chosen because of their association with caries identified through previous research.

Analysis of the relationship between MS and visible plaque revealed that these two variables do not have a statistically significant relationship (p = 0.212). However, examination of frequencies between categories reveals that although the relationship is not significant, there appears to be a trend in the anticipated direction. The majority of the children presenting with *high* or *very high* MS levels also had *moderate* visible plaque levels. Furthermore, most of the children with *low* to *moderate* MS levels were within the *none* or *mild* plaque categories (Table 4.3 – MS and Plaque Inter-Variable Association).

Table 4.3

MS and Plaque Inter-Variable Association

	None		Mild		Moderate		Severe				
Oral Mutans	*n*	(%)	*n*	(%)	*n*	(%)	*n*	%	χ^2	*df*	*p*
Low	8	(29.6)	17	(34)	9	(34.6)	1	(20)			
Moderate	18	(66.7)	32	(64)	12	(46.2)	3	(60)			
High	1	(3.7)	0	(0)	3	(11.5)	1	(20)			
Very High	0	(0)	1	(2)	2	(7.7)	0	(0)			
Total	27	(100)	50	(100)	26	(100)	5	(100)	1.555	1	0.212

Note. χ^2 = Chi Square; *df* = degrees of freedom.

Similar to the previous analysis, the Chi-Square procedure was used in the analysis of association between MS levels and presence of decalcification. This analysis did not find a statistically significant relationship between these variables (Table 4.4 – MS and Decalcification Inter-Variable Association**)**. Despite a lack of statistical significance, the relationship between

MS and decalcification appears to be in the expected direction. The majority of participants who had *low* or *moderate* MS levels had no evidence of decalcification. Moreover, although there were very few children with *high* or *very high* MS levels, the majority of them presented with evidence of decalcification.

Table 4.4

MS and Decalcification Inter-Variable Association

	No		Yes				
Oral Mutans	*n*	(%)	*n*	(%)	χ^2	*df*	*p*
Low	24	(33.8)	11	(29.7)			
Moderate	44	(62)	21	(56.8)			
High	2	(2.8)	3	(8.1)			
Very High	1	(1.4)	2	(5.4)			
Total	71	(100)	37	(100)	1.68	1	0.195

Note. χ^2 = Chi Square; *df* = degrees of freedom.

The Chi-Square analysis of the relationship between MS and ECC Status revealed that these variables are significantly correlated ($p < 0.001$) (Table 4.5 – MS and ECC Inter-Variable Association). The majority of child participants who did not meet the diagnostic criteria for ECC or S-ECC also presented with *low* to *moderate* MS levels. Furthermore, although there were very few children presenting with *very high* levels of MS, they all met the diagnostic criteria for S-ECC.

Table 4.5

MS and ECC Inter-Variable Association

	No ECC		ECC		S-ECC				
Oral Mutans	*n*	(%)	*n*	(%)	*n*	(%)	χ^2	*df*	*p*
Low	27	(50.9)	1	(7.1)	7	(17.1)			
Moderate	24	(45.3)	12	(85.7)	29	(70.7)			
High	2	(3.8)	1	(7.1)	2	(4.9)			
Very High	0	(0)	0	(0)	3	(7.3)			
Total	53	(100)	14	(100)	41	(100)	13.471	1	0.000

Note. χ^2 = Chi Square; *df* = degrees of freedom.

Analysis of data on presence of visible plaque and decalcification also revealed a statistically significant relationship ($p < 0.001$) (Table 4.6 – Plaque and Decalcification Inter-Variable Association). The Chi-Square procedure indicated that the majority of children presenting with no evidence of visible plaque also presented without evidence of decalcification. Additionally, the majority of children categorized as having *severe* visible plaque levels also presented with evidence of decalcification.

Table 4.6

Plaque and Decalcification Inter-Variable Association

	No		Yes				
Visible Plaque	*n*	(%)	*n*	(%)	χ^2	*df*	*p*
None	24	(33.8)	3	(8.1)			
Mild	33	(46.5)	17	(45.9)			
Moderate	13	(18.3)	13	(35.1)			
Severe	1	(1.4)	4	(10.8)			
Total	71	(100)	37	(100)	13.547	1	0.000

Note. χ^2 = Chi Square; *df* = degrees of freedom.

The association between visible plaque and ECC status was also evaluated via the Chi-Square procedure. This analysis revealed a statistically significant relationship between these two variables (p = 0.032) (Table 4.7 – Plaque and ECC Status Inter-Variable Association). Results from the Chi-Square analysis indicate that the majority of children who failed to meet the diagnostic criteria for ECC presented within the *none* and *mild* categories of visible plaque. Additionally, most of the children who met the diagnostic criteria for S-ECC also presented with some evidence of visible plaque. In contrast to the expected direction of the relationship between these variables, nearly half of the children presenting with *severe* visible plaque did not meet the diagnostic criteria for ECC or S-ECC.

Table 4.7

Plaque and ECC Status Inter-Variable Association

	No ECC		ECC		S-ECC				
Visible Plaque	*n*	(%)	*n*	(%)	*n*	(%)	χ^2	*df*	*p*
None	18	(34)	3	(21.4)	6	(14.6)			
Mild	23	(43.4)	9	(64.3)	18	(43.9)			
Moderate	9	(17)	2	(14.3)	15	(36.6)			
Severe	3	(5.7)	0	(0)	2	(4.9)			
Total	53	(100)	14	(100)	41	(100)	4.619	1	0.032

Note. χ^2 = Chi Square; *df* = degrees of freedom.

Lastly, the relationship between decalcification and ECC status was explored using Chi-Square analysis as well. This analysis indicated that there is a statistically significant relationship ($p < 0.001$) between these two physical indicators of caries risk (Table 4.8 – Decalcification and

ECC Status Inter-Variable Association). The majority of children presenting without evidence of decalcification also failed to meet the diagnostic criteria for ECC or S-ECC, whereas the majority of participants with evidence of decalcification did meet the criteria for either ECC or S-ECC diagnosis.

Table 4.8

Decalcification and ECC Status Inter-Variable Association

	No ECC		ECC		S-ECC				
Decalcification	*n*	(%)	*n*	(%)	*n*	(%)	χ^2	*df*	*p*
No	44	(83)	8	(57.1)	19	(46.3)			
Yes	9	(17)	6	(42.9)	22	(53.7)			
Total	53	(100)	14	(100)	41	(100)	13.889	1	0.000

Note. χ^2 = Chi Square; *df* = degrees of freedom.

In summary, all four physical indicators of caries evaluated in the DECC study were fairly well correlated with one another. Interestingly, statistically significant relationships between MS and visible plaque as well as MS and decalcification were not found in the DECC study population; however, all other relationships among the physical indicators of interest were found to be significant (Table 4.9 – Summary of Inter-Variable Associations).

Table 4.9

Summary of Inter-Variable Associations

	Oral Mutans	Visible Plaque	Decalcification	ECC Status
Oral Mutans	-			**
Visible Plaque		-	**	*
Decalcification		**	-	**
ECC Status	**	*	**	-

Note. χ^2 = Chi Square; *df* = degrees of freedom; * $p < 0.05$; ** $p < 0.001$.

Demographic associations. Ordinal Logistic Regression (OLR) was used to explore the existence of associations between physical indicators of caries and key demographic variables (Table 4.10 – Demographics and Physical Indicators of Caries Associations OLR). The OLR analysis revealed that presence of decalcification was significantly associated with child age (p = 0.011) and borderline associated with sex (p = 0.061). According to the OLR analysis, as age increases, we can expect to observe an increase in the likelihood of having decalcification. Furthermore, since sex of the child was also borderline associated with presence of decalcification, the results from OLR suggest that males may have been more likely to have decalcification than females in the DECC study sample population.

An association between age and ECC status was also observed (p = 0.052), with higher age being associated with classification within the ECC or S-ECC category. This finding was not surprising, as the diagnostic criteria for ECC is dependent upon dfs, which is a measure of lifetime caries experience; thus one's dfs index can only increase with age.

Because sex and age appear to be associated with several of the outcome variables of interest, these variables were held constant in all subsequent OLR analyses in order to address their potentially confounding effect.

Table 4.10

Demographics and Physical Indicators of Caries Associations OLR

	Oral Mutans			Visible Plaque			Decalcification			ECC Status		
	Logit	*OR*	*p*	Logit	*OR*	*p*	Logit	*OR*	*p*	Logit	*OR*	*p*
Sex	0.396	1.49	0.326	0.579	1.78	0.117	0.81	2.25	0.061	0.437	1.55	0.253
Race/ Ethnicity	0.812	2.25	0.173	0.229	1.26	0.680	0.341	1.41	0.618	0.334	1.4	0.572
Weight Status	0.326	1.39	0.192	0.083	1.09	0.709	0.026	1.03	0.922	0.135	1.14	0.561
Age	0.067	1.07	0.692	-0.095	0.91	0.542	0.504	1.66	0.011	0.324	1.38	0.052

Note. OR = odds ratio; Sex was evaluated as males versus females; race as Hispanic versus others; and weight as overweight versus others.

In order to further investigate the relationships between age and physical indicators of caries, children in the DECC study were stratified by age, and divided into quintiles (Table 4.11 – Age Quintile Descriptive Analysis). The age quintiles were then analyzed via Chi-Square analysis to investigate the existence of significant associations with physical indicators of caries risk.

Table 4.11

Age Quintile Descriptive Analysis

Age Quintile	*n*	*M*	*Minimum*	*Maximum*
Q1	21	2.5	2	2.98
Q2	22	3.43	3.01	3.82
Q3	22	4.31	3.88	4.61
Q4	22	4.99	4.62	5.39
Q5	21	5.85	5.42	6.7
Total	108	4.22	2	6.7

Note. Age represented in years; *M* = mean age.

The Chi-Square analyses revealed that age quintile was significantly associated with both the presence of decalcification and ECC status (Table 4.12 – Age Quintiles by Physical Indicators of Caries). Analysis of age quintiles was performed in order to address the fact that younger children may be less likely to present with evidence of the later stages of the caries disease process than older children. This is believed to be a result of the increased time necessary to manifest these late stages of disease progression; younger children may not have had enough time to develop later indicators of caries.

4.4.2 – Frequency of food and beverage intake. In order to assess overall frequency of food and beverage intake, total number of eating and drinking occurrences (oral exposures) was tallied using data from the MSB modified 24-hour dietary recall. This frequency value was used to indicate total number of oral exposures (intake of food and/or beverages) reported for the 24-hour period preceding data collection. The total number of oral exposures reported by DECC study participants ranged from 3 to 12. On average, participants reported a mean total of 5.42 (*SD* = 1.72) eating and/or drinking occurrences during the modified 24-hour dietary recall.

Table 4.12

Age Quintiles by Physical Indicators of Caries

Physical Indicator	Age Quintile							
	Q1	Q2	Q3	Q4	Q5			
	n	*n*	*n*	*n*	*n*	χ^2	*df*	*p*
Oral Mutans								
Low	7	9	8	6	5			
Moderate	12	11	12	16	14			
High	0	2	2	0	1			
Very High	2	0	0	0	1			
Total	21	22	22	22	21	0.097	1	0.755
Visible Plaque								
None	7	7	4	2	7			
Mild	6	7	14	13	10			
Moderate	7	6	4	6	3			
Severe	1	2	0	1	1			
Total	21	22	22	22	21	0.175	1	0.676
Decalcification								
No	20	13	17	8	13			
Yes	1	9	5	14	8			
Total	21	22	22	22	21	7.491	1	0.006
ECC Status								
No ECC	15	13	10	9	6			
ECC	0	0	4	4	6			
S-ECC	6	9	8	9	9			
Total	21	22	22	22	21	4.27	1	0.039

Note. χ^2 = Chi Square; *df* = degrees of freedom.

Analysis of intake frequency by physical indicators of caries. Frequency of intake was then evaluated against measures of physical evidence of caries to determine if number of oral exposures is associated with caries risk in the study population. Total number of oral exposures was compared to physical indicators of caries risk for each child via two statistical methods: Analysis of Variance (ANOVA) and OLR. Initially, frequency of intake was evaluated via ANOVA to identify if a significant difference in intake frequency exists between children presenting within the various categories of physical indicators of caries risk. The ANOVA procedure is not the most appropriate method of analysis for ordinal outcome variables; therefore, ANOVA results are presented here primarily for descriptive purposes. ANOVA provides useful information regarding trends in mean scores that may be helpful in illustrating the relationship between variables. OLR results will be presented following the ANOVA table, to provide a more precise measure of the significance of the relationships between variables.

Review of the mean number of oral exposures from the ANOVA table, in comparison to varying levels of MS and visible plaque, suggest that there may be a slight trend in children presenting with higher levels of these physical indicators and higher reported frequency of intake, though the relationships were not significant (Table 4.13 – Frequency of Intake by Physical Indicators of Caries ANOVA).

Intake frequency was then evaluated via OLR to provide a more accurate assessment of its relationship to physical indicators of caries. Since the outcome variables of interest are ordinal categorical variables, the OLR procedure is a more appropriate method of analysis than ANOVA. OLR allows for the interpretation of results, while accounting for the rank ordered nature of the variable categories. OLR revealed that total number of oral exposures reported via modified 24-hour recall did not exhibit a statistically significant association with physical indicators of caries risk (Table 4.14 – Frequency of Intake by Physical Indicators of Caries OLR).

Table 4.13

Frequency of Intake by Physical Indicators of Caries ANOVA

Physical Indicator		Intake Frequency (Number of Oral Exposures)				
	n	*M*	*SD*	*df*	*F*	*p*
Oral Mutans						
Low	35	5.23	1.750			
Moderate	65	5.48	1.640			
High	5	5.40	2.074			
Very High	3	6.33	3.215			
Total	108	5.42	1.725	3	0.44	0.724
Visible Plaque						
None	27	5.44	1.867			
Mild	50	5.34	1.791			
Moderate	26	5.46	1.363			
Severe	5	5.80	2.387			
Total	108	5.42	1.725	3	0.12	0.948
Decalcification						
No	71	5.54	1.919			
Yes	37	5.19	1.266			
Total	108	5.42	1.725	1	0.98	0.325
ECC Status						
NO ECC	53	5.40	1.790			
ECC	14	5.57	2.102			
S-ECC	41	5.39	1.531			
Total	108	5.42	1.725	2	0.06	0.938

Note. df = degrees of freedom.

Table 4.14

Frequency of Intake by Physical Indicators of Caries OLR

Physical Indicator	Logit	*OR*	*p*
Oral Mutans	0.118	1.13	0.318
Visible Plaque	-0.011	0.99	0.921
Decalcification	-0.103	0.9	0.437
ECC Status	0.029	1.03	0.794

Note. Participant age and sex are held constant in this OLR analysis; *OR* = odds ratio.

Intake frequency was also categorized by type of intake occurrence (i.e., *meal, snack,* or *beverage*). The *beverage* category includes only those non-water beverages consumed in isolation; this does not include any beverages consumed in combination with food. Data on type of intake occurrence were then evaluated to investigate associations with physical indicators of caries. The descriptive analysis of this data revealed that children in the DECC study apparently consumed an average of 2.84 *meals*, 1.44 separate *snacks,* and 1.09 discrete *beverages* (not consumed as part of a *meal* or *snack*) during the 24 hours preceding administration of the MSB assessment tool (Table 4.15 – Meal/Snack/Beverage Descriptive Analysis).

Table 4.15

Meal/Snack/Beverage Descriptive Analysis

Intake Occurrence Type	Minimum	Maximum	*M*
Meal	1	4	2.84
Snack	0	5	1.44
Beverage	0	6	1.09

Note. †This includes only non-water beverages consumed in isolation, apart from food.

When data were analyzed via OLR, frequency of *meal* intake was found to exhibit a borderline significant relationship with MS (Table 4.16 – Meal/Snack/Beverage Frequency by Physical Indicators of Caries OLR). This analysis suggests that higher intake of *meals* is associated with higher levels of MS. Additionally OLR analysis suggests that a borderline significant relationship may exist between increased frequency of *meals* and ECC status (Table 4.16 – Meal/Snack/Beverage Frequency by Physical Indicators of Caries OLR).

Table 4.16

Meal/Snack/Beverage Frequency by Physical Indicators of Caries OLR

Intake Occurrence Type	Logit	*OR*	*p*
Meal			
Oral Mutans	0.535	1.71	0.053
Visible Plaque	0.013	1.01	0.96
Decalcification	0.112	1.12	0.707
ECC Status	0.445	1.56	0.1
Snack			
Oral Mutans	-0.132	0.88	0.442
Visible Plaque	-0.085	0.92	0.592
Decalcification	-0.116	0.89	0.557
ECC Status	0.085	1.09	0.612
Beverage†			
Oral Mutans	0.135	1.14	0.445
Visible Plaque	0.031	1.03	0.844
Decalcification	-0.169	0.84	0.391
ECC Status	-0.17	0.84	0.323

Note. Participant age and sex are held constant in this OLR analysis; *OR* = odds ratio; †This includes only non-water beverages consumed in isolation, apart from food.

4.4.3 – Food and beverage categories. The modified 24-hour recall component of MSB included a total of 32 categories (25 food and 7 beverage categories) representing the majority of items consumed by children in the target population. Dietary intake data extracted from the 24-hour recall module of the assessment tool included measures of frequency of intake per category for each participant (continuous variable, with count of intake occurrence). The modified 24-hour recall module revealed that children consumed both cariogenic and non-cariogenic foods.

The most common non- and low-cariogenic food categories consumed were *meat* (*n* = 72; 66.7%), and *unsweetened grain products* (*n* = 102; 94.4%), respectively. The most commonly consumed cariogenic food categories included *sauces* (*n* = 19; 17.6%) and *cake like desserts* (*n* = 28; 25.9%). The most common non- and low-cariogenic beverage categories consumed were *plain water or seltzer* (*n* = 91; 84.3%) and *plain milk* (*n* = 76; 70.4%), respectively. Conversely, the most commonly consumed cariogenic beverages were the *juice and juice drinks* category (*n* = 71; 65.7%), with reported intake up to five times/day (Table 4.17 – Food/Beverage Category Descriptive Analysis).

In addition to these descriptive analyses, data collected on participant consumption of food/beverage categories were also analyzed in relation to physical evidence of caries risk. Analysis of food/beverage categories was performed in three different ways in order to investigate any potential relationships with outcome variables that may exist. Analyses were initially performed by evaluation of frequency of consumption for each individual food/beverage category. Following individual category analysis, the food/beverage categories were grouped by assigned cariogenicity score (as indicated in MSB; see Appendix F – MSB Food/Beverage Categories and Cariogenicity). Evaluation of frequency data for grouped categories was then performed in the same manner as the individual category analysis. Lastly, evaluation of associations between physical indicators of caries and proportion of intake of food/beverage categories within the non-cariogenic food group and non-cariogenic beverage group was analyzed. Findings from these analyses are presented below.

Analysis of individual food/beverage categories by physical indicators of caries. Evaluation of intake frequency data for individual food and beverage categories was conducted via OLR analysis for each of the 32 categories by each of the 4 physical indicator variables, separately. Food/beverage categories that were consumed by four or less children were not included in this analysis in order to stabilize the data, adhere to assumptions of the OLR model and avoid misinterpretation of extraneous relationships.

Analysis of frequency data on individual food/beverage categories revealed that several categories exhibited statistically significant relationships with physical indicators of caries. Only those food/beverage categories that exhibited a statistically significant ($p < 0.05$) or nearly significant ($p < 0.10$) relationship with physical indicators of caries are presented in the table below (Table 4.18 – Individual Food/Beverage Categories by Physical Indicators of Caries OLR). As the table indicates, 27, 30, 31, and 25 categories were not significant, or close to significant, for MS, plaque, decalcification, and ECC status, respectively. Several of the statistically significant relationships were in the expected direction based on previous studies (i.e., the *candies*, *sweetened yogurt, sauces*, and *peanut butter and jelly sandwich* categories all exhibit a positive relationship with physical indicators of caries). For example, OLR indicates that for each additional intake of food within the *candies* category, the odds of having higher MS levels (*moderate, high,* or *very high*) as opposed to *low* MS increase by a multiple of 25.89.

Table 4.17

Food/Beverage Category Descriptive Analysis

Category	Consumed		Frequency			
	n	(%)	0	1	>1	Max.
Non-Cariogenic Food	100	(92.6)	8	42	50	6
Meat	72	(66.7)	36	50	22	3
Egg	35	(32.4)	73	33	2	3
High Fiber Vegetable	34	(31.5)	74	28	6	2
Cheese	31	(28.7)	77	24	7	3
Nuts	1	(0.9)	107	1	0	1
Low-Cariogenic Food	107	(99.1)	1	4	103	8
Unsweetened Grain Product	102	(94.4)	6	33	69	5
Fruit	59	(54.6)	49	45	14	3
Starchy Vegetable	53	(49.1)	55	39	14	3
Soup	23	(21.3)	85	21	2	2
Meat or Cheese Sandwich	13	(12)	95	13	0	1
Cariogenic Liquid Food	48	(44.4)	60	33	15	3
Sauces	19	(17.6)	89	18	1	2
Sweeteners	15	(13.9)	93	14	1	2
Sweetened Yogurt	14	(13)	94	14	0	1
Cold Dessert	12	(11.1)	96	9	3	2
Pizza	12	(11.1)	96	11	1	3
Macaroni and Cheese	8	(7.4)	100	8	0	1
High-Cariogenic Food	75	(69.4)	33	47	28	6
Cake Like Dessert	28	(25.9)	80	26	2	2
Salty Snack Food	21	(19.4)	87	18	3	3
Sweetened Cereal	12	(11.1)	96	12	0	1
Candies	9	(8.3)	99	9	0	1
Peanut Butter/Jelly Sandwich	7	(6.5)	101	6	1	2
Granola Bar	4	(3.7)	104	4	0	1
Hard Candy	4	(3.7)	104	4	0	1
Spread	2	(1.9)	106	2	0	1
Dried Fruit	2	(1.9)	106	2	0	1
Non-Cariogenic Beverage	91	(84.3)	17	44	47	5
Plain Water or Seltzer	91	(84.3)	17	46	45	5
Diet and Non-Sugar Drink	1	(0.9)	107	1	0	1
Vegetable Juice	1	(0.9)	107	1	0	1
Low-Cariogenic Beverage	76	(70.4)	32	37	39	3
Plain Milk	76	(70.4)	32	37	39	3
Cariogenic Liquid Beverage	90	(83.3)	18	32	58	6
Juice and Juice Drinks	71	(65.7)	37	45	26	5
Flavored Milk	33	(30.6)	74	21	13	3
Sugared/Sweetened Beverages	28	(25.9)	80	23	5	2

In contrast to these findings, OLR identified several significant associations that were not in the anticipated direction (i.e., the *egg*, *plain milk*, *cheese*, and *high fiber vegetable* categories exhibited a positive relationship with physical indicators); suggesting that higher intake of foods within these categories is associated with increased physical indicators of caries risk. It is unclear why these other factors were in the unanticipated direction; perhaps it is due to other foods that are consumed in combination with these categories.

Table 4.18

Individual Food/Beverage Categories by Physical Indicators of Caries OLR

Variable	*n*	(%)	Logit	*OR*	*p*
Oral Mutans					
Candies†	9	(8.3)	3.254	25.89	0.001
Unsweetened Grain Product†	102	(94.4)	-0.547	0.58	0.072
Flavored Milk†	33	(30.6)	0.628	1.87	0.075
Egg	35	(32.4)	1.473	4.36	0.001
Plain Milk	76	(70.4)	0.7	2.01	0.028
Oral Plaque					
Sweetened Yogurt†	14	(13)	1.727	5.62	0.006
Peanut Butter and Jelly Sandwich†	7	(6.5)	1.68	5.37	0.019
Decalcification					
High Fiber Vegetables	34	(31.5)	1.109	3.03	0.038
ECC Status					
Sauces†	19	(17.6)	1.541	4.67	0.02
Sweetened Yogurt†	14	(13)	1.556	4.74	0.023
Candies†	9	(8.3)	2.141	8.51	0.028
Unsweetened Grain Product†	102	(94.4)	-0.476	0.62	0.09
Plain Milk	76	(70.4)	0.848	2.33	0.006
Egg	35	(32.4)	1.198	3.31	0.014
Cheese	31	(28.7)	0.82	2.27	0.035

Note. Participant age and sex held constant in this analysis; *OR* = odds ratio; †Relationship in expected direction.

Analysis of food/beverage cariogenicity groups by physical indicators of caries. Each of the 32 food and beverage categories were divided into groups based on their assigned cariogenicity in the MSB tool. Using assigned MSB cariogenicity scores, these categories were divided into four food groups (non-cariogenic food, low-cariogenic food, cariogenic liquid food, and high-cariogenic food) and three beverage groups (non-cariogenic beverage, low-cariogenic beverage, and cariogenic liquid beverage). Data on frequency of intake for these cariogenicity groups were evaluated for each child against their physical evidence of caries risk. The same OLR analysis procedure that was used to evaluate individual food/beverage categories was employed in the analysis of the categories grouped by cariogenicity (Table 4.19 – Food/Beverage Cariogenicity Groups by Physical Indicators of Caries OLR).

The OLR analysis revealed that a statistically significant relationship between cariogenicity groups and physical indicators of caries did not exist; however, two groups did exhibit nearly significant relationships ($p < 0.10$). Contrary to what was anticipated, those children with higher reported intake of food within the non-cariogenic food group appear to have been more likely to have a higher level of MS than children with a lower reported intake. Another nearly significant relationship can be observed with intake of food within the cariogenic liquid food category. As anticipated, children with higher reported intake of food from the cariogenic liquid food category appear to have been more likely to exhibit higher MS levels than children with lower intake of food within this cariogenicity group (Table 4.19 – Food/Beverage Cariogenicity Groups by Physical Indicators of Caries OLR).

Evaluation of the results for the relationship between intake of the high cariogenic food group and the non-cariogenic beverage group also reveal an association in the expected direction, though not statistically significant. OLR revealed that higher intake of foods within the high cariogenic food group appears to be positively associated MS, plaque, and ECC; whereas intake of higher frequencies of beverages within the non-cariogenic beverage category appears to be associated with lower levels of physical indicators of caries risk (Table 4.19 – Food/Beverage Cariogenicity Groups by Physical Indicators of Caries OLR).

Proportional analysis of non-cariogenic food/beverage groups by physical indicators of caries. Intake frequency was also analyzed by evaluating the proportion of foods and beverages consumed that were categorized as the *non-cariogenic food* group and *non-cariogenic beverage* group, respectively. Each non-cariogenic group was evaluated by assessing the proportion of intake within the group versus all other groups. Although the OLR analysis did not reveal any statistically significant relationships, one nearly significant association was observed in the anticipated direction (Table 4.20 – Proportion Non-Cariogenic Groups Relative to All Food/Beverage Groups by Physical Indicators of Caries OLR). The relationship between increased consumption of non-cariogenic beverages, relative to all beverages consumed, was found exhibit borderline significance (p = 0.066) with decreased MS levels, suggesting that children with higher intake of non-cariogenic beverages relative to all beverages may be less likely to present with higher levels of MS.

Table 4.19

Food/Beverage Cariogenicity Groups by Physical Indicators of Caries OLR

	Non-Cariogenic Food	Low Cariogenic Food	Cariogenic Liquid Food	High Cariogenic Food	Non-Cariogenic Beverage	Low Cariogenic Beverage	Cariogenic Liquid Beverage
Oral Mutans							
Logit	0.26	0.057	-0.079	0.007	-0.13	0.108	0.253
OR	1.3	1.06	0.92	1.01	0.88	1.11	1.29
P	0.094	0.729	0.761	0.974	0.522	0.646	0.161
Visible Plaque							
Logit	0.006	-0.081	0.267	0.063	-0.148	-0.061	0.111
OR	1.01	0.92	1.31	1.07	0.86	0.94	1.12
P	0.967	0.587	0.265	0.732	0.428	0.778	0.492
Decalcification							
Logit	0.156	0.012	-0.16	-0.196	-0.11	0.193	-0.168
OR	1.17	1.01	0.85	0.82	0.9	1.21	0.85
P	0.348	0.948	0.583	0.404	0.638	0.463	0.427
ECC Status							
Logit	0.114	0.081	0.523	0.002	-0.219	0.354	-0.092
OR	1.12	1.08	1.69	1	0.8	1.42	0.91
p	0.445	0.614	0.051	0.99	0.285	0.132	0.601

Note. Participant age and sex are held constant in this OLR analysis; *OR* = odds ratio.

Table 4.20

Proportion Non-Cariogenic Groups Relative to All Food/Beverage Groups by Physical Indicators of Caries OLR

	Proportion of Non-Cariogenic Food: All Foods			Proportion of Non-Cariogenic Beverage: All Beverages		
	Logit	*OR*	*p*	Logit	*OR*	*p*
Oral Mutans	1.784	5.95	0.204	-1.926	0.15	0.066
Visible Plaque	1.879	6.55	0.144	0.187	1.21	0.843
Decalcification	-0.163	0.85	0.913	0.16	1.17	0.884
ECC Status	-0.9	0.41	0.499	0.216	1.24	0.825

Note. Participant age and sex are held constant in this OLR analysis; *OR* = odds ratio.

4.4.4 – MSB risk scores. The diet assessment component of MSB generated a weighted risk score, based on data collected from the modified 24-hour recall module. As previously described, each of the food and beverage categories in the modified 24-hour recall module were assigned a weight within the MSB tool, from zero to four, based on estimated cariogenicity (Appendix F – MSB Food/Beverage Categories and Cariogenicity) (Levine et al., 2012). For foods/beverages consumed in combination, an average of the weighted scores was calculated by MSB (Levine et al., 2012). If the averaged score for an intake occurrence was greater than 3, it was considered to be a “risky” occurrence. The total number of these risky occurrences was then summed for the day and assigned a total weight which contributes to a child’s MSB diet risk score (Levine et al., 2012). The diet risk score was then combined with risk data from the other four assessment areas of MSB to create a comprehensive MSB risk assessment score.

MSB diet risk score. The diet risk score generated by MSB provided ordinal data which categorized participants based on calculated risk score of 0 (*low*), 1 (*moderate*), 6 (*high*), or 9 (*very high*). These scores were based on the following classification criteria: 0 risky occasions = 0 risk score; 1-2 risky occasions = 1 risk score; and 3-4 risky occasions = 6 risk score; 5 or more = 9 risk score. Descriptive analysis of MSB diet risk score data reveal that the majority of DECC study participants received a *moderate* risk score (54.6%), with the next most frequent being a *low* score (33.3%) (Table 4.21 – MSB Diet Risk Score Descriptive Analysis). Only two participants (10.2%) received a *high* diet score.

Table 4.21

MSB Diet Risk Score Descriptive Analysis

Diet Risk Score	*n*	(%)
Low	36	(33.3)
Moderate	59	(54.6)
High	11	(10.2)
Very High	2	(1.9)

Analysis of MSB diet score by physical indicators of caries. The MSB diet risk score was compared to physical indicators of caries risk for each child via ANOVA and OLR. Initially, ANOVA was used to identify if a significant difference in MSB diet score exists between children presenting within the various categories of physical indicators of caries risk. ANOVA revealed that a significant difference does exist with regard to both MS levels and visible plaque (Table 4.22 – MSB Diet Risk by Physical Indicators of Caries ANOVA). Despite the limitations of ANOVA in appropriately interpreting significance of relationships with ordinal outcome variables, it is helpful to understand mean trends. Examination of the mean MSB diet risk scores for children within each of the levels of MS and visible plaque reveals that children with higher levels of MS and plaque also received higher MSB diet risk scores. Those children who presented with the highest levels of MS (*high* and *very high*) and visible plaque (*moderate* and *severe*) received a higher score, on average, than those with lower levels of these physical indicators (Table 4.22 – MSB Diet Risk by Physical Indicators of Caries ANOVA).

MSB diet risk score was then evaluated via OLR for associations with physical indicators of caries risk. The OLR analysis revealed that MS levels exhibited a statistically significant relationship with MSB diet score (Table 4.23 – MSB Diet Risk by Physical Indicators of Caries OLR). The OLR analysis indicates that higher levels of MS are associated with higher MSB diet scores (p = 0.031). For every one unit increase in MSB diet risk score, the odds of having *moderate, high,* or *very high* MS levels, as opposed to *low* MS levels, increase by a multiple of 1.26. Additionally, there was a borderline signficant relationship (p = 0.061) in the anticipated direction between visible plaque levels and MSB score.

Table 4.22

MSB Diet Risk by Physical Indicators of Caries ANOVA

Physical Indicator		MSB Diet Risk Score					
	n	Scores	*M*	*SD*	*df*	*F*	*p*
Oral Mutans							
Low	35	0, 1, 6	0.94	1.35			
Moderate	65	0, 1, 6, 9	1.38	2.08			
High	5	0, 1, 6	1.8	2.39			
Very High	3	1, 9	3.67	4.62			
Total	108	0, 1, 6, 9	1.32	1.99	1	5.46	0.021
Visible Plaque							
None	27	0, 1, 6	0.96	1.53			
Mild	50	0, 1, 6, 9	1.18	1.92			
Moderate	26	0, 1, 6, 9	1.69	2.29			
Severe	5	0, 1, 6	2.8	2.95			
Total	108	0, 1, 6, 9	1.32	1.99	1	4.21	0.043
Decalcification							
No	71	0, 1, 6, 9	1.48	2.18			
Yes	37	0, 1, 6	1.03	1.57			
Total	108	0, 1, 6, 9	1.32	1.99	1	1.25	0.267
ECC Status							
NO ECC	53	0, 1, 6	1.36	1.88			
ECC	14	0, 1, 9	1.21	2.29			
S-ECC	41	0, 1, 6, 9	1.32	2.09			
Total	108	0, 1, 6, 9	1.32	1.99	2	0.03	0.972

Note. df = degrees of freedom.

Table 4.23

MSB Diet Risk by Physical Indicators of Caries OLR

Physical Indicator	Logit	*OR*	*p*
Oral Mutans	0.228	1.26	0.031
Visible Plaque	0.175	1.19	0.061
Decalcification	-0.076	0.93	0.532
ECC Status	0.034	1.03	0.725

Note. Participant age and sex are held constant in this OLR analysis; *OR* = odds ratio.

The data were then analyzed by age quintile via OLR for associations between physical indicators of caries and MSB *Diet* risk scores. The OLR analyses on associations with MS and visible plaque were performed by successively eliminating older age quintiles; conversely, analyses on associations with decalcification and ECC status were performed by successively eliminating younger age quintiles. The quintiles were successively eliminated in order to identify the existence of any significant associations between these variables that may differ between older versus younger children in the DECC study sample population.

The OLR analysis by successive elimination of older age quintiles revealed that there is a significant association between MSB *Diet* risk score and MS (Table 4.24 – Effect of Successively Eliminating Older/Younger Age Quintiles in Analysis of MSB Diet Risk by Physical Indicators of Caries OLR). Data suggest that for all age quintiles, except for the youngest of children (Q1), there appears to be an association between MSB *Diet* score and MS, whereby higher MSB *Diet* risk is associated with higher MS levels. This finding thus suggests that MSB *Diet* risk score is sensitive to varying degrees of MS; this relationship was also evident in the previous analysis when all ages were analyzed jointly.

Table 4.24

Effect of Successively Eliminating Older/Younger Age Quintiles in Analysis of MSB Diet Risk by Physical Indicators of Caries OLR

Variable by Age Quintile	*n*	Logit	*OR*	*p*
Oral Mutans				
≤ Q4 (up to 5.39 years)	87	0.218	1.24	0.049
≤ Q3 (up to 4.61 years)	65	0.265	1.0	0.026
≤ Q2 (up to 3.82 years)	43	0.331	1.39	0.024
≤ Q1 (up to 2.98 years)	21	0.25	1.28	0.171
Visible Plaque				
≤ Q4 (up to 5.39 years)	87	0.15	1.16	0.122
≤ Q3 (up to 4.61 years)	65	0.122	1.13	0.245
≤ Q2 (up to 3.82 years)	43	0.167	1.18	0.178
≤ Q1 (up to 2.98 years)	21	0.014	1.01	0.927
Decalcification†				
≥ Q2 (3.01 years and above)	87	-0.051	0.95	0.696
≥ Q3 (3.88 years and above)	65	-0.249	0.78	0.244
≥ Q4 (4.62 years and above)	43	-0.087	0.92	0.72
≥ Q5 (5.42 years and above)	21	-0.865	0.42	0.523
ECC Status†				
≥ Q2 (3.01 years and above)	87	0.052	1.05	0.657
≥ Q3 (3.88 years and above)	65	0.061	1.06	0.661
≥ Q4 (4.62 years and above)	43	0.123	1.13	0.537
≥ Q5 (5.42 years and above)	21	0.565	1.76	0.254

Note. Participant sex is held constant in this OLR analysis; *OR* = odds ratio; †OLR performed by successively eliminating younger age quintiles.

Comprehensive MSB risk score. The comprehensive MSB risk score for DECC participants ranged from 1 to 8 (out of a possible 10), with a mean of 3.52 (*SD* = 1.17). Descriptive examination of the data, reveal that the lower and upper extremes for comprehensive MSB risk score (scores = 1, 6, 7, and 8) included very few (*n* = 1) participants (Table 4.25 – Comprehensive MSB Risk Score Descriptive Analysis).

Table 4.25

Comprehensive MSB Risk Score Descriptive Analysis

Comprehensive MSB Risk Score	*n*	(%)
Low		
1	1	(0.9)
2	18	(16.7)
3	42	(38.9)
Medium		
4	24	(22.2)
5	20	(18.5)
6	1	(0.9)
High		
7	1	(0.9)
8	1	(0.9)

As previously noted, the *Comprehensive* MSB risk score combines the MSB *Diet* score with information obtained from a series of additional ECC risk questions included in the MSB assessment tool. These questions were chosen as contributors to the *Comprehensive* risk score because of their potential ability to evaluate mediators of behavior change associated with the theoretical models utilized during the design of the MSB tool. In order to provide additional detail regarding the contributing factors to the *Comprehensive* MSB risk score, descriptive analyses were performed on these additional ECC risk questions (Table 4.26 – Comprehensive MSB Score Questions Descriptive Analysis).

These analyses suggest that the majority of DECC study participants were engaging in positive dental health behaviors prior to completion of the MSB assessment tool. The high proportion of participants who reported having taken their child to the dentist for a routine check-up in the previous 12 months (n = 83; 76.9%), suggests that it is likely that the majority of participants previously received oral health education or instruction; thus, they may have already initiated positive behavior changes prior to administration of the MSB tool.

Analysis of comprehensive MSB score by physical indicators of caries. The comprehensive MSB risk score was analyzed in the same manner as the MSB diet risk score. The comprehensive MSB risk score for each child was compared with physical indicators of caries via ANOVA as well as OLR. The ANOVA procedure revealed that both MS and visible plaque are significantly associated with comprehensive MSB risk score (Table 4.27 – Comprehensive MSB Risk by Physical Indicators of Caries ANOVA). Review of the means indicate that comprehensive MSB risk scores increase as levels of MS and visible plaque increase, thus higher comprehensive risk scores are associated with higher levels of these physical indicators of caries.

Since OLR is a more appropriate method than ANOVA for evaluating data with ordinal outcome variables, OLR was used to more accurately investigate the relationship between comprehensive MSB risk score and physical indicators of caries. Similarly to MSB diet risk score, comprehensive MSB score appears to be associated with both MS and visible plaque levels (Table 4.28 – Comprehensive MSB Risk by Physical Indicators of Caries OLR).

Table 4.26

Comprehensive MSB Score Questions Descriptive Analysis

Question	Frequency	(%)
Has your child had a routine dental check-up in the last 12 months?		
Yes	83	(76.9)
No	25	(23.1)
How often do you put your child to bed with a bottle or sippy cup with anything other than water?		
Always	9	(8.3)
Often	2	(1.9)
Sometimes	9	(8.3)
Never	88	(81.5)
How often does your child sip a sugared drink from a sippy cup or bottle throughout the day?		
Always	8	(7.4)
Often	5	(4.6)
Sometimes	27	(25)
Never	68	(63)
How often do you clean your child's pacifier by putting it in your mouth?		
Missing Data	12	(11.1)
Always	0	(0)
Often	1	(0.9)
Sometimes	2	(1.9)
Never	93	(86.1)
What is your child's main source of drinking water?		
Bottled	34	(31.5)
Tap	43	(39.8)
Both	31	(28.7)
Have you (parent or caregiver) ever had an abscessed tooth?		
Yes	26	(24.1)
No	82	(75.9)
What type of toothpaste does your child most routinely use?		
Kids' brands without fluoride	9	(8.3)
Kids' brands with fluoride	70	(64.8)
Adult brands with fluoride	17	(15.7)
A variety of pastes	12	(11.1)
Most of the mothers I know brush their children's teeth daily. How much would you say you agree with this statement?		
I agree	81	(75)
I disagree	7	(6.5)
I'm not sure	20	(18.5)
How confident are you in reducing your child's risk for tooth decay?		
Confident	95	(88)
Not Confident	5	(4.6)
I'm not sure	8	(7.4)

Table 4.27

Comprehensive MSB Risk by Physical Indicators of Caries ANOVA

Physical Indicator		Comprehensive MSB Risk Score					
	n	Scores	*M*	*(SD)*	*df*	*F*	*p*
Oral Mutans							
Low	35	1-5	3.37	0.97			
Moderate	65	2-6, 8	3.48	1.2			
High	5	2, 4, 5, 7	4.4	1.82			
Very High	3	4, 5	4.67	0.58			
Total	108	1-8	3.52	1.17	1	5.01	0.027
Visible Plaque							
None	27	2-6	3.44	1.12			
Mild	50	1-5	3.26	1.01			
Moderate	26	2-5, 8	3.92	1.29			
Severe	5	3-5, 7	4.4	1.67			
Total	108	1-8	3.52	1.7	1	4.37	0.039
Decalcification							
No	71	1-6, 8	3.55	1.22			
Yes	37	2-5, 7	3.46	1.1			
Total	108	1-8	3.52	1.17	1	0.14	0.707
ECC Status							
NO ECC	53	2-7	3.7	1.12			
ECC	14	2-5	3	0.88			
S-ECC	41	1-5, 8	3.46	1.29			
Total	108	1-8	3.52	1.17	2	2.08	0.13

Note. df = degrees of freedom.

Unlike MSB diet score, however, comprehensive MSB risk score exhibits a statistically significant relationship with both of these physical indicators. The OLR analysis suggests that higher levels of MS and higher levels of visible plaque (p = 0.035 and p = 0.043, respectively) are both associated with higher comprehensive MSB risk Scores. For every one-unit increase in comprehensive MSB risk score, the odds of exhibiting higher levels of MS (*moderate, high,* or *very high*) and visible plaque (*mild, moderate,* or *severe*) increase by a multiple of 1.49 and 1.41, respectively.

Table 4.28

Comprehensive MSB Risk by Physical Indicators of Caries OLR

Physical Indicator	Logit	*OR*	*p*
Oral Mutans	0.397	1.49	0.035
Visible Plaque	0.345	1.41	0.043
Decalcification	0.142	1.15	0.489
ECC Status	-0.063	0.94	0.726

Note. Participant age and sex are held constant in this OLR analysis; *OR* = odds ratio.

Much like the previous analyses of MSB *Diet* risk scores, the *Comprehensive* MSB risk score was analyzed by age quintile via OLR to identify associations with physical indicators of caries risk. The OLR analyses on associations with MS and visible plaque were performed by successively eliminating older age quintiles; conversely, analyses on associations with decalcification and ECC status were performed by successively eliminating younger age quintiles. The quintiles were successively eliminated in order to identify the existence of any significant associations between these variables that may differ between older versus younger children in the DECC study as a result of the nature of disease progression; younger children may not have had adequate time to develop later stage indicators of caries.

The OLR analyses revealed that by eliminating the oldest age quintile, higher *Comprehensive* MSB scores are significantly associated with presence of visible plaque (Table

4.29 – Effect of Successively Eliminating Older/Younger Age Quintiles in Analysis of Comprehensive MSB Risk by Physical Indicators OLR). Similarly, by eliminating the two oldest age quintiles, visible plaque exhibits a borderline significant association with *Comprehensive* MSB risk score. Thus, this analysis suggests that the *Comprehensive* MSB risk score is sensitive to varying levels of visible plaque, while accounting for the inherent difference in the opportunity for disease manifestation between children of varying ages. This finding was similar to that revealed in the analysis of children in the DECC study when all ages were combined and analyzed together.

Interestingly, the OLR analysis by age quintile revealed a significant association between presence of decalcification and *Comprehensive* MSB risk score, which was not identified when analyzing all ages together (Table 4.29 – Effect of Successively Eliminating Older/Younger Age Quintiles in Analysis of Comprehensive MSB Risk by Physical Indicators OLR). After successive elimination of the younger age quintiles, decalcification was identified as significantly associated with *Comprehensive* MSB risk score; thereby suggesting that MSB may be sensitive to differences in children with decalcification versus those without. This analysis suggests that as the *Comprehensive* MSB risk score increases, likelihood of presenting with decalcification increases as well, for children in the upper age quintiles (Q4 and above). Evaluation of odds ratio values also indicates a notable increase in the odds of obtaining a higher *Comprehensive* MSB risk score with presence of decalcification among older versus younger children.

Table 4.29

Effect of Successively Eliminating Older/Younger Age Quintiles in Analysis of Comprehensive MSB Risk by Physical Indicators OLR

Variable by Age Quintile	*n*	Logit	*OR*	*p*
Oral Mutans				
≤ Q4 (up to 5.39 years)	87	0.284	1.33	0.152
≤ Q3 (up to 4.61 years)	65	0.286	1.33	0.165
≤ Q2 (up to 3.82 years)	43	0.186	1.2	0.442
≤ Q1 (up to 2.98 years)	21	0.129	1.14	0.722
Visible Plaque				
≤ Q4 (up to 5.39 years)	87	0.366	1.44	0.045
≤ Q3 (up to 4.61 years)	65	0.322	1.38	0.098
≤ Q2 (up to 3.82 years)	43	0.379	1.46	0.102
≤ Q1 (up to 2.98 years)	21	0.41	1.51	0.227
Decalcification†				
≥ Q2 (3.01 years and above)	87	0.167	1.18	0.445
≥ Q3 (3.88 years and above)	65	0.197	1.22	0.508
≥ Q4 (4.62 years and above)	43	1.16	3.19	0.036
≥ Q5 (5.42 years and above)	21	1.306	3.69	0.14
ECC Status†				
≥ Q2 (3.01 years and above)	87	-0.111	0.89	0.582
≥ Q3 (3.88 years and above)	65	0.034	1.03	0.898
≥ Q4 (4.62 years and above)	43	0.632	1.88	0.118
≥ Q5 (5.42 years and above)	21	-0.22	0.8	0.701

Note. Participant sex is held constant in this OLR analysis; *OR* = odds ratio; †OLR performed by successively eliminating younger age quintiles.

4.4.5 – Length of Eating or Drinking Occurrence.

Quick/slow eater/drinker question. In order to assess a general pattern of dietary intake associated with caries risk, prolonged oral exposure time, a simple question was incorporated into the MSB risk assessment tool to evaluate typical length of eating/drinking occurrence (i.e., typical eating/drinking pace). All participants were asked, "Is your child a quick eater/drinker, or a slow eater/drinker?" Responses provided dichotomous categorical data labeled as *quick* and *slow*. The majority of DECC study participants stated that their child was a quick eater/drinker (*n* = 80; 74%) (Table 4.30 – Quick/Slow Eater/Drinker Question Descriptive Analysis). Male and female children were nearly equally likely to be identified as quick eaters/drinkers (74.5% of males; 73.8% of females) and slow eaters/drinkers (25.5% of males; 26.2% of females).

Table 4.30

Quick/Slow Eater/Drinker Question Descriptive Analysis

Response	Total Sample		Males		Females	
	n	(%)	*n*	(%)	*n*	(%)
Quick	80	(74.1)	35	(74.5)	45	(73.8)
Slow	28	(25.9)	12	(25.5)	16	(26.2)

Quick/slow eater/drinker question by physical indicators of caries. The stated response to this question was then evaluated against physical indicators of caries risk to identify if a relationship exists between stated intake pace and caries risk. OLR analysis did not reveal the existence of a statistically significant relationship between perceived child intake pace (quick/slow eater/drinker question) and physical evidence of caries (Table 4.31 – Quick/Slow Eater/Drinker by Physical Indicators of Caries OLR).

Table 4.31

Quick/Slow Eater/Drinker by Physical Indicators of Caries OLR

Physical Indicator	Logit	*OR*	*p*
Oral Mutans	0.184	1.2	0.679
Visible Plaque	0.268	1.31	0.519
Decalcification	0.714	2.04	0.18
ECC Status	0.282	1.33	0.523

Note. Participant age and sex are held constant in this OLR analysis; *OR* = odds ratio.

Paper-based one-day food record. For the purpose of collecting and analyzing data on dietary intake patterns, a subset of the population (n = 31) provided additional data in the form of a paper-based one-day food record (Appendix L – One-Day Food Record). All participants were presented with the opportunity to participate in this additional study activity. A total of 91 participants agreed to complete the food record. Of those who were recruited to participate in the 24-hour food record activity, 34 participants (37.4%) returned completed food records. Three of the food records received were not completed in their entirety and were thus eliminated from inclusion in data analysis.

The food records were designed to collect start/end times of food/beverage intake occurrences to allow for the calculation of the duration of each eating/drinking occurrence. This duration information was then used to determine the total oral exposure time (in minutes) over a one-day period as well as average oral exposure time per intake occurrence (Table 4.32 – One-Day Food Record Oral Exposure Time Descriptive Analysis). The data collected from the one-day food record revealed that total oral exposure time (sum total of oral exposure time for all intake occurrences over a one-day period) was on average 176.16 minutes (*SD* = 78.84). Additionally, average oral exposure time per intake occurrence (average time per eating/drinking occasion during a one-day period) was on average 31.55 minutes (*SD* = 14.12).

Table 4.32

One-Day Food Record Oral Exposure Time Descriptive Analysis

Variable	Minimum	Maximum	*M* (*SD*)
Total Oral Exposure Time	59	360	176.16 (78.84)
Average Oral Exposure Time	8	78	31.55 (14.12)

Note. Time represented in minutes.

Paper-based one-day food record by physical indicators of caries. Analysis of food record oral exposure time by physical indicators of caries via ANOVA did not reveal any clear trends in means; however, it appears that children presenting with the higher levels of MS and plaque tended to have the highest total and average oral exposure times. Analysis via OLR was then performed as a more accurate way to assess the relationship between both total and average oral exposure time and physical evidence of caries risk. The OLR analysis did not identify a statistically significant relationship between either of the oral exposure time variables and any of the four physical indicators of caries risk evaluated (Table 4.33 – One-Day Food Record Oral Exposure Time by Physical Indicators OLR).

Table 4.33

24-Hour Food Record Oral Exposure Time by Physical Indicators OLR

	Total Oral Exposure Time			Average Oral Exposure Time		
Physical Indicator	Logit	*OR*	*p*	Logit	*OR*	*p*
Oral Mutans	0.001	1	0.908	0.02	1.02	0.475
Visible Plaque	-0.003	0.99	0.567	0.018	1.02	0.494
Decalcification	0.007	1.01	0.264	0.000	1	0.994
ECC Status	-0.001	1	0.813	-0.026	0.97	0.515

Note. Participant age and sex are held constant in this OLR analysis; *OR* = odds ratio.

4.4.6 – BMI/age percentile. Analysis of anthropometric data allowed for calculation of BMI/Age percentiles and subsequent categorization by weight status. Data revealed that the majority of children recruited for the DECC study were within a healthy weight range (68.5%) however, nearly one quarter of participants (23.1%) were found to be either overweight (8.3%) or obese (14.8%), with a small percentage underweight (8.3%) according to BMI/Age categorization (Table 4.34 – BMI/Age Categorical Weight Status Descriptive Analysis).

BMI/age weight status by physical indicators of caries. Physical evidence of caries risk was evaluated against BMI/age percentile and categorical weight status to determine if an association between these variables exists. Review of the mean BMI/age percentiles for varying levels of the physical indicators of caries reveals that there is no clear trend in the measures (Table 4.35 – BMI/age Percentile by Physical Indicators of Caries ANOVA).

Table 4.34

BMI/Age Categorical Weight Status Descriptive Analysis

	Total Sample		Males		Females	
Weight Status	*n*	(%)	*n*	(%)	*n*	(%)
Underweight (< 5^{th} Percentile)	9	(8.3)	1	(2.1)	8	(13.1)
Healthy Weight (5^{th} to < 85^{th} Percentile)	74	(68.5)	35	(74.5)	39	(63.9)
Overweight (85^{th} to < 95^{th} Percentile)	9	(8.3)	2	(4.3)	7	(11.5)
Obese (≥ 95^{th} Percentile)	16	(14.8)	9	(19.1)	7	(11.5)

Analysis was then performed via OLR as a more appropriate way of evaluating the relationship between BMI/age and physical indicators of caries. The OLR analysis did not indicate that a statistically significant relationship exists between child weight status and physical indicators of caries risk (Table 4.36 – BMI/age Weight Status by Physical Indicators of Caries OLR).

Table 4.35

BMI/age Percentile by Physical Indicators of Caries ANOVA

Physical Indicator		BMI/Age Percentile				
	n	*M*	*SD*	*df*	*F*	*p*
Oral Mutans						
Low	35	52.7829	34.90374			
Moderate	65	59.4785	31.61994			
High	5	72.9800	28.59322			
Very High	3	50.7333	26.08109			
Total	108	57.6907	32.41168	3	0.75	0.528
Visible Plaque						
None	27	63.2963	26.20764			
Mild	50	53.9680	36.31834			
Moderate	26	63.3231	30.96582			
Severe	5	35.3600	16.46111			
Total	108	57.6907	32.41168	3	1.57	0.202
Decalcification						
No	71	55.1380	33.64314			
Yes	37	62.5892	29.73241			
Total	108	57.6907	32.41168	1	1.29	0.259
ECC Status						
NO ECC	53	51.6189	33.68022			
ECC	14	79.5143	29.75841			
S-ECC	41	58.0878	28.84363			
Total	108	57.6907	32.41168	2	4.37	0.015

Note. df = degrees of freedom.

Table 4.36

BMI/age Weight Status by Physical Indicators of Caries OLR

Variable	Logit	*OR*	*p*
Oral Mutans	0.326	1.39	0.192
Visible Plaque	0.083	1.09	0.709
Decalcification	0.026	1.03	0.922
ECC Status	0.135	1.14	0.561

Note. Participant age and sex are held constant in this OLR analysis; *OR* = odds ratio.

4.4.7 – Summary of Physical Indicator Correlation Analyses. The following table provides an overview of the findings from the aforementioned OLR analyses on physical indicators of caries risk (Table 4.37 – Overview of Physical Indicators of Caries OLR Correlation Analyses). Statistically significant ($p < .05$) associations as well as marginally significant ($p < .10$) findings are presented symbolically. Overall, physical indicators of caries risk were found to be associated (or marginally associated) with several of the variables of interest in the DECC study. Both MSB diet and comprehensive risk scores were found to be significantly associated with MS levels, and visible plaque levels exhibited a borderline relationship with MSB diet score, and a significant relationship with the comprehensive MSB risk score. Furthermore, several food/beverage categories and cariogenicity groups were also found to exhibit potential relationships with physical indicators of caries as well.

4.4.8 – One-month follow-up survey. For those participants who were successfully reached for one-month follow-up ($n = 79$; 73.1%), researchers administered a telephone-based survey which asked participants about their recollection of the DECC study activities. Participants were asked if they recalled completing the MSB risk assessment tool and setting a behavioral goal in MSB to reduce their child's ECC risk. Participants were also asked if they had made any changes in their child's diet and/or oral health habits as a result of the information they received during their participation in the study.

Table 4.37

Overview of Physical Indicators of Caries OLR Correlation Analyses

Predictor Variables	Oral Mutans	Visible Plaque	Decalcification	ECC Status
Intake Frequency				
Non-Cariogenic Food Group	†			
Low Cariogenic Food Group				
Cariogenic Liquid Food Group				†
High Cariogenic Food Group				
Non-Cariogenic Beverage Group				
Low Cariogenic Beverage Group				
Cariogenic Beverage Group				
Proportion Non-Cariogenic Beverage Group	†			
Proportion Non-Cariogenic Food Group				
MSB Diet Risk Score	*	†		
Comprehensive MSB Risk Score	*	*	*	
Quick/Slow Eater/Drinker Response				
Average Oral Exposure Time				
Total Oral Exposure Time				
BMI Weight Status				

Note. See Appendix R for complete table with exact p-values; * $p < 0.05$; † $p < 0.10$; Participant age and sex was held constant in these OLR analyses; Comprehensive MSB risk score significantly associated with decalcification only via analyses by age quintile.

On average, the follow-up survey was administered 41.22 (*SD* = 7.66) days after recruitment and completion of the MSB assessment tool. A total of 76 participants (96.2%) who completed the follow-up survey recalled the MSB risk assessment tool (Table 4.38 – One-Month Follow-Up Outcome Descriptive Analysis).

Table 4.38

One-Month Follow-Up Outcome Descriptive Analysis (n = 79)

Recalled MSB		Recalled MSB Goal- Setting		Correctly Stated MSB Goal[†]		Steps Taken to Achieve MSB Goal		Other Stated Changes	
n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
76	(96.2)	50	(63.3)	48	(60.8)	54	(68.4)	42	(53.2)

Note. [†]If unable to state MSB goal, researchers reminded participants of goal and proceeded to assess actions taken to achieve behavior change.

Post-intervention behavior change. Out of the 79 participants who completed the follow-up survey, 50 (63.3%) recalled setting a behavioral goal as part of the MSB tool and 48 (60.8%) were able to successfully state their chosen MSB behavior goals. Additionally, a total of 54 participants (68.4%) reported having taken action to facilitate achievement of stated MSB goals (Table 4.38 – One-Month Follow-Up Outcome Descriptive Analysis). Examples of stated actions included, "…buy Cheetos® once per month and start buying yogurt", "Water is added to juice… avoid buying sweets", "Replace juice for water".

Of the 79 DECC participants who completed the one-month follow-up survey, 36 (45.6%) set diet-related behavior change goals in MSB. Another 35 (44.3%) set dental-related goals, and the remaining 8 participants (10.1%) set a combination of diet- and dental-related goals. The stated behavior change goals were reviewed and organized into ten categories, representing the major themes that emerged from the goal data. The frequencies and percentages for each of the goal themes are presented in the table below (Table 4.39 – MSB Goal Behavioral Themes). Since many participants stated behavioral goals that included more than one diet/dental-related action, several of the participants' goals were categorized into more than one theme.

Table 4.39

MSB Goal Behavioral Themes (n = 79)

	MSB Goal	
Behavioral Theme	*n*	(%)
Limit Sweet Foods/Snacks†	26	(32.9)
Limit/Dilute Sweet Beverages†	22	(27.8)
Increase Water†	7	(8.9)
Stop Bedtime Food/Beverage†	4	(5.1)
Visit/Consult Dentist Regularly	8	(10.1)
Eat Healthier†	3	(3.8)
Increase Flossing/Mouthwash	3	(3.8)
Transition to Regular Cups†	1	(1.3)

† Diet-related Goal

Participants were also asked if they initiated additional behavioral changes, beyond those set via MSB, to promote reduction of ECC risk. Of the 79 participants who completed the one-month follow-up survey, 42 (53.2%) reported having initiated *other* behavioral changes (aside from stated MSB goals) in their child's diet or oral health habits (Table 4.38 – One-Month Follow-Up Outcome Descriptive Analysis). Of the participants who reported that they did not take steps to achieve their MSB behavioral goals, nine stated that they initiated *other* changes; therefore, a total of 63 (79.7%) of participants reported engaging in some kind of action (either related to MSB or *other* goals) to change behavior post-intervention. These, *other*, behavioral changes were also classified as either diet-related (n = 25; 59.5%), dental-related (n = 9; 21.4%), or a combination of the two (n = 8; 19%), and categorized by goal theme as well (Table 4.40 – Other Stated Change Behavioral Themes).

Table 4.40

Other Stated Change Behavioral Themes (n = 79)

	Other Stated Changes	
Behavioral Theme	*n*	(%)
Eat Healthier†	18	(22.8)
Limit/Dilute Sweet Beverages†	13	(16.5)
Limit Sweet Foods/Snacks†	10	(12.7)
Increase Flossing/Mouthwash	7	(8.9)
Increase Water†	6	(7.6)
Stop Bedtime Food/Beverage†	1	(1.3)
Stop Sharing Utensils†	1	(1.3)

† Diet-related Goal

CHAPTER 5

Discussion

This chapter provides a discussion of the results obtained via analysis of data collected during the DECC study. Interpretation of study findings, comparison of findings to other relevant studies, discussion of study strengths and limitations, and potential implications for future application of MSB are presented.

5.1 - Study Purpose

The Diet and Early Childhood Caries (DECC) study was designed to validate a novel risk assessment tool, MySmileBuddy (MSB), for the identification of children at risk for Early Childhood Caries (ECC), in a predominantly minority, Spanish-speaking, low-income population. A primary aim of the DECC study was to establish concurrent criterion validity of the MSB tool by determining if diet and dietary intake patterns, as assessed by MSB, are associated with physical indicators of caries risk (i.e., oral mutans, visible plaque, decalcification, and ECC status). This study also sought to investigate the relationships between several other diet-related caries risk factors (i.e., frequency and cariogenicity of oral exposure, length of oral exposure time, BMI percentile for age) and physical evidence of caries risk. Finally, the DECC study was designed to provide preliminary data on the potential use of the MSB tool for diet- and dental-related behavior change.

5.2 – Validation of MSB Diet and Comprehensive Risk Scores

One of the main goals of the DECC study was to validate the MSB risk assessment tool by establishing concurrent criterion validity. The DECC study was successful in demonstrating that *Comprehensive* MSB scores were, indeed, associated with both oral mutans levels, as well as visible plaque. Children with higher *Comprehensive* MSB scores were more likely to have higher levels of oral mutans and more likely to have higher levels of plaque. Results were similar for the MSB *Diet* scores as well.

It is unclear why the MSB *Diet* and *Comprehensive* risk scores were associated with oral mutans and plaque, but not associated with decalcifications or ECC. This finding may suggest that MSB is better at predicting risk of caries (as evidenced by its association with the early stage indicators of caries risk), as opposed to actual presence of tooth decay (as evidenced by its lack of association with the later stage indicators of caries risk). Perhaps children with previously identified caries may have previously been advised and were already in the process of making positive changes to their diet or oral health behaviors at the time of assessment. Additionally, the lack of association between MSB scores and decalcification or ECC may be related to the possibility that younger children simply may not have had enough time to develop these later indicators of caries, compared to older children. Thus, it should be noted that since analysis by age quintile revealed a significant association between MSB *Comprehensive* risk and decalcification in older (but not younger) children, and a potential relationship with ECC status (although the small sample size likely limited these findings), further investigation into the utility of MSB to identify older children with these stages of disease is warranted.

Regardless, the finding that MSB *Diet* and *Comprehensive* scores are associated with early indicators of caries risk is very promising. The American Academy of Pediatric Dentistry (AAPD) recognizes the importance of early risk assessment in the prevention and management of ECC, however, the association acknowledges that there are no assessment tools, to date, that can ensure accurate categorization of children by risk or predict future caries experience through clinical application (Pediatric Oral Health Research and Policy Center, 2012). By identifying children at the earliest stages of the caries development process, MSB may hold the potential to fill this void in current risk assessment tools. Future application of the MSB tool in a larger prospective study may provide a more clear indication of its ability to predict, and ultimately prevent, future caries.

One of the unique aspects of the MSB tool is that the *Diet* risk score adjusts for the consumption of combinations of foods with varying degrees of cariogenicity. In other words, the MSB tool takes into account whether or not a high cariogenic food or beverage (e.g., crackers) is consumed in combination with other foods or beverages that may be protective (e.g., cheese). This is preferred over basing risk on individual items consumed because of the potential buffering effect of low/non-cariogenic foods/beverages on those with higher cariogenicity. Additionally, this method may help account for the decreased cariogenic potential of foods consumed in combination as a result of the beneficial effect of increased salivary flow (Mobley, 2003; Sanders, 2004; Touger-Decker & van Loveren, 2003). This may be why the DECC study found limited and inconsistent associations between physical indicators of caries and frequency of individual food/beverage categories.

Another unique feature of the MSB tool is that it was designed to assess overall risk by incorporating several known risk factors of ECC, from multiple levels of influence. The AAPD suggests that ECC risk assessment models should incorporate evaluation of a multitude of ECC-related factors, including diet-related behaviors, fluoride exposure, susceptibility of the individual, socioeconomic status, cultural influences, and oral health behaviors (American Academy of Pediatric Dentistry, 2011/2012). MSB was designed to do just that, which is one potential reason why associations between physical indicators of caries and the individual risk factors (e.g., individual intake of food/beverage categories, or oral exposure time) evaluated in the DECC study did not result in as robust findings as the evaluation of the associations with the *Comprehensive* MSB risk score. Descriptive analysis of the additional risk questions included in the MSB tool, that are ultimately combined with the MSB *Diet* score to create the *Comprehensive* score, revealed that most of the DECC participants reported engaging in healthful oral- and diet-related behaviors. This may be attributed to the fact that nearly 77 percent of parents/caregivers reported having taken their child to the dentist during the previous year. Therefore, it is possible that these participants received oral health instruction and guidance, which may have been already implemented, prior to administration of the MSB tool. Future investigations of the MSB tool, including evaluation of the supplementary questions incorporated in the tool that do not currently contribute to determination of risk scores, may provide insight into other important caries-related factors that should be weighted in the calculation of the *Comprehensive* MSB risk score.

Although the MSB association with MS and plaque are similar to other ECC tools that have shown relationships with physical indicators (Domejean, White, & Featherstone, 2011;

Holgerson, et al., 2009; Yoon, et al., 2012), MSB has an advantage because not only is it assessing risk, but it is also using that risk to tailor oral health education messages. The behavioral factors that contribute to the MSB risk scores inform the recommendations for goal setting that are presented to the parent/caregiver upon completion of the assessment tool, and are thus highly individualized and risk-based. The one-month follow-up survey results from the DECC study provide preliminary data to suggest that the majority of MSB participants were taking steps to achieve their MSB goals, but use of the MSB tool in a longer-term randomized controlled trial would be necessary to evaluate its true potential to influence behavior change and, ultimately, physical indicators of risk.

5.3 – Frequency of Oral Exposures and Outcomes

Perhaps one of the most unexpected findings from the DECC study was that we did not observe a clear association between frequency of oral exposures and physical indicators of caries, despite evidence in the literature to support this relationship (Edmondson, 1990; Gustafsson et al., 1954; Krasse, 2001; Marshall et al., 2005). This finding was surprising since many of the current ECC risk assessment tools use frequency of exposures (overall or between meals) or number of highly cariogenic food/beverages as a way to predict children at risk for ECC (Bratthall & Hansel Petersson, 2005; Francisco, et. al., 2007; Marshall, 2009). The DECC study findings were in contrast to findings from highly controlled experimental studies which found strong associations with caries risk factors, like the classic Vipeholm study; however, this may speak to the inherently complicated and difficult to measure nature of caries risk. Because

ECC is a multifactorial disease, which is influenced by numerous factors at various levels of influence, risk cannot be fully assessed by evaluation of single measures (e.g., individual foods/beverages consumed, or frequency of exposures). The DECC study allowed for assessment of numerous factors at once via the MSB tool, which is likely a contributing factor to the clearer associations observed between physical indicators of caries and MSB scores, versus other measures. Furthermore, sheer frequency of intake does not account for the effect of foods consumed in combination versus those consumed in isolation, which MSB does account for. In the DECC study, children with lower levels of MS and plaque had a slightly lower number of daily oral exposures, but these findings were not statistically significant. Since MSB scores (*Diet* and *Comprehensive* scores) *were* associated with MS and plaque, and frequency of oral exposures was not, we believe that this emphasizes the importance of adjustment for combinations of foods with varying degrees of cariogenicity. Simply asking about overall intake frequency or number of high cariogenic foods in general may not be as useful a predictor as a composite score of foods consumed in combination.

Moreover, analysis of food/beverage intake occurrences by type of occurrence (i.e., *meal, snack,* or *beverage*) suggests that further investigation into the analysis of intake type is warranted to evaluate its contribution to caries risk. Despite the ability to designate intake occurrences as *meals* or *snacks* in the modified 24-hour dietary recall module of MSB, this information was not consistently documented in the DECC study; therefore, future evaluations of the MSB tool should incorporate accurate collection of data on intake occurrence type. Despite the inability to use self-reported occurrence type in the DECC study, evaluation of subjective assignment of occurrence type yielded interesting findings. It does appear, as previous studies have suggested, that frequency of intake when evaluated by number of *meals* is associated with MS; in contrast, we did not find associations with frequency of between-meal, or *snack*, intake as other studies have reported.

The DECC study also evaluated relationships between physical indicators of caries and cariogenicity of individual food/beverage categories. This analysis did not yield many clear associations, and those that were found to be significant were not necessarily in the anticipated direction. There did, however, appear to be a few exceptions in that the increased intakes in the categories of *candy, sweetened yogurt, peanut butter & jelly sandwiches,* and *sauces* were significantly associated with worse physical indicators of caries. For candy, in particular, for each additional intake of food within the candies category, the odds of having higher MS levels (*moderate, high,* or *very high*) as compared to low MS, increased by a multiple of ~25. Future versions of the MSB application may consider whether or not these particular categories of foods should be weighted more heavily in their contribution to the overall MSB diet score.

5.4 – Length of Oral Exposure and Outcomes

The link between prolonged oral exposure time and ECC risk has been well established (see section 2.5.2 – Intake patterns, oral exposure time, and dental caries), however existing ECC risk assessment tools fail to include assessment of eating/drinking pace as a risk factor. In the DECC study, we tried to develop a measure of exposure time that would be associated with physical indicators of caries that could potentially be included in future versions of the MSB tool and incorporated into the *Comprehensive* MSB risk score. In order to assess the utility of such a measure, the DECC study investigated the association between the length of oral exposure time (measured two different ways: single quick/slow eater/drinker question and one-day food record) and physical indicators of caries. The results suggest that there was no association with outcomes regardless of whether we used a single question ("Is your child a quick or slow eater/drinker?), or a more comprehensive assessment of intake pace (based on a one-day food record with actual meal and snack times recorded). Findings are in contrast to other studies that found an association between oral exposure time and caries (R Harris et al., 2004; Heller et al., 2001; C. Palmer et al., 2010).

It was interesting that the majority (74.1%) of parents/caregivers in the DECC study reported their children to be *quick* eaters/drinkers, yet the average oral exposure based on one-day food records was 31.55 minutes (or 176.16 minutes for the day) - a length of time that seems to be more indicative of a *slow* eater/drinker than a *quick* eater/drinker. This finding raises concern about the potential utility of both measures.

According to previous research on caries risk assessment, the DECC study population appears to have an average oral exposure time (> 30 minutes) that would place them at high risk for caries (Marshall, 2009). Regardless, the fact that we did not find an association may suggest that further efforts are needed to develop a better way of assessing length of oral exposure time. Recording length of meals/snacks/beverages can be challenging, particularly when the 'start' and 'end' time of a meal is often unclear with young children. One possibility for more accurately assessing oral exposure time might be for future studies to conduct observations of meal and snack times within the child's home. For now, including a question on length of eating/drinking exposures does not seem warranted to include in MSB.

5.5 – BMI for Age Percentile and Outcomes

Previous research has been somewhat inconclusive regarding the relationship between weight status and caries, however obesity has been hypothesized to have a shared etiology with ECC (Reifsnider et al., 2004; Touger-Decker, 2007; Tuomi, 1989; Willershausen et al., 2004). Conversely, poor oral health has also been shown to cause decreased appetite and diminished ability to eat, resulting in unintentional weight loss (Mofidi, Zeldin, & Rozier, 2009; C. Palmer et al., 2010; Papas et al., 1989). Within the DECC study population, BMI/age percentile and weight status categorization were not found to exhibit a statistically significant relationship with physical indicators of caries risk.

Although not statistically significant, an interesting finding was that BMI/age percentiles were lower for those children presenting with the most extreme categories of risk (*very high* MS, *severe* plaque, and *S-ECC*) compared to other groups. The DECC study sample had too few participants in these extreme categories to explore this relationship in depth, but it would be interesting for future studies to investigate whether children with the most severe disease have lower BMI/age percentiles because of an impaired ability to eat as a result of their poor oral health status.

5.6 – Using MSB to Achieve Behavioral Changes

Preliminary data based on the one-month follow-up survey is promising. Data suggest that almost all participants recalled completing the MSB assessment and the majority remembered, and could state, their MSB behavior goal. This may be related to the fact that MSB was quite well received by participants, likely due to its visual appeal and interactive design. The MSB tool is colorful, interactive, and uses visually appealing images of children, caregivers, and food/dental products. Additionally, MSB provides recommendations for behavior change goals based on individual risk. This tailored approach allows for delivery of key educational and behavioral messages based on the individual's responses. The provision of targeted messages likely enhanced recollection of MSB goals by participants.

Upon follow-up, nearly 70% of participants reported that they were actively working towards achieving their goal, and 50% were actively working towards additional goals beyond those set via MSB. These encouraging findings may be related to the fact that MSB was developed on the basis of several theoretical models of behavior change and incorporates evaluation of numerous determinants of behavior at varying levels of influence in order to create individualized behavior change guidance. Thus, the guidance participants received via MSB, to encourage positive behaviors to reduce ECC risk, were highly individualized, which likely impacted both recollection and adoption of MSB goals.

Interestingly, slightly more participants reported having taken steps to achieve their MSB goal, than were able to initially recall the MSB goal-setting activity. This may perhaps be related to the fact that the follow-up survey specifically asked participants if they remembered what their "goal" was; however, it should be noted that participants might not have associated their intended behavior changes with the term "goal". Moreover, the researcher conducting the follow-up survey reminded participants of their MSB goal if they initially stated that they did not recall setting a goal during administration of the MSB tool.

Overall, the findings from the follow-up survey are promising, considering the fact that the DECC study only employed a one-time follow-up call. MSB offers the potential for repeated contact with participants, whereby progress on goals and behavior change can be both monitored and reinforced. Repeated contact and prolonged intervention with MSB would permit establishment of rapport, and would allow for continued tailored behavior change support, whereby goals can be adjusted and risk can be repeatedly reassessed. The follow-up survey outcomes strongly support the potential utility of the MSB risk assessment tool as a valuable behavior change tool. Further investigation into the application of the MSB tool as a useful platform for education, goal setting, and positive behavior change is certainly warranted.

Despite these promising findings, it was somewhat discouraging that 26.9% of DECC participants were lost to follow-up; however, this lost to follow-up rate was not surprising. This attrition rate emphasizes the challenges of working with a hard-to-reach population. Temporary loss of communication with patients frequently occurs as a result of families returning to their native countries, often for extended periods of time. Many of these families revisit the clinic for oral healthcare services upon returning to New York at a much later date. Furthermore, current telephone contact information can be difficult to maintain when families temporarily relocate, move, or change cell phone carriers.

Evaluation of demographic characteristics revealed that those participants who completed the one-month follow-up survey did not significantly differ from those who were lost-to-follow-up (Appendix S - Comparison of Lost-to-Follow-Up and One-Month Survey Completers). However, those participants who were not reached for follow-up may be precisely the ones that need the help most.

One of the benefits of MSB is that it does not have to be used in a dental setting, where people have already made a decision to seek oral health care. Because MSB was created to be administered via a portable electronic device (iPad) and is not reliant on continuous connectivity to the internet or a power source and may be used virtually anywhere; thereby increasing its usability in countless community-based settings. For example, MSB could be administered in WIC clinics, Head Start programs, schools, or other community-based settings. Additionally, MSB may be used by pediatricians or within other child healthcare settings. If so, it could be modified to meet the needs of a busy medical office. MSB can also be administered by a trained layperson, thus making it a potentially valuable tool for community health workers or social workers in a variety of settings. Use of MSB outside of dental settings may facilitate the ability to reach individuals at the highest risk of oral health problems. Those individuals who are not currently seeking oral health care are the ones we most want to reach and target for intervention.

5.7 – Strengths

Nearly 96% of individuals presented with the opportunity to join the study agreed to participate and completed the MSB assessment tool. This extremely high acceptance rate likely speaks to the tremendous interest of parents to learn more about promoting optimal oral health in their young children. The DECC study researchers recorded noteworthy comments on many participants regarding their interest in the study topic, reported history of oral health problems, and general comments that may have impacted caries risk or study outcomes. Over three quarters of the relevant comments recorded (comments regarding study procedures were excluded) expressed high parent/caregiver interest in oral health or diet education, and/or desire to prevent oral health problems due to significant personal (or child) history of poor oral health. Thus, it appears parents/caregivers of young children are eager for enhanced knowledge of diet- and dental-related health issues.

The DECC study was conducted under "real-life" conditions in a very busy dental clinic, as opposed to a controlled research setting. Despite the challenges inherent in working in an active community clinic, the procedures employed in this investigation were feasible and could potentially be carried out in other community-based settings. MSB was designed to have minimal participant burden, to be engaging, and to provide minimal reliance on literacy abilities. These attributes of the MSB risk assessment tool make it a useful and practical tool for administration among diverse populations with various challenges that may include limited time, attention, and written comprehension. Therefore, future applications of the MSB risk assessment tool in a variety of venues are merited.

Another significant strength of the MSB tool is that it was customized to be culturally appropriate for the DECC study target population. This tool included foods, beverages, and behaviors that are culturally appropriate and relevant to the predominantly Hispanic, low-income population in the communities served by the dental clinic. Photographs of specific brands of foods and beverages from neighborhood bodegas were specifically used in this study to ensure familiarity with food/beverage items included in the modified 24-hour recall module. In addition to the tool being culturally appropriate, the DECC study employed the use of bilingual researchers to minimize issues related to language barriers. Despite the fact that all researchers were bilingual, they did not necessarily share the same cultural background as the DECC study participants. This is worth noting because there are slight variations in phrases and pronunciations between different dialects within Spanish-speaking countries. Despite these potential differences, all researchers collecting data and administering the MSB tool were able to communicate well with participants in their preferred language; thereby building rapport and trust while also facilitating administration of study procedures and data collection.

5.8 – Limitations

The findings of the DECC study must be considered within the context of the study's limitations. The DECC study had a limited sample size with 108 parent/child (caregiver/child) dyads. Several of the associations in the DECC study were borderline significant, which may have been statistically significant if a larger sample size had been included.

A potential limitation associated with data collection is the subjectivity inherent in clinical examination findings. Several of the physical indicators of caries risk were clinician-dependent, in that they were open to the interpretation of the individual conducting the examination. These findings may thus be interpreted differently amongst clinicians.

Classification of visible plaque levels, recognition of decalcifications, and identification of cavitations (active versus incipient and/or arrested carious lesions) all hold the potential to be interpreted differently depending on the individual clinician's professional opinion. The DECC study addressed this issue by recognizing the fact that all clinicians participating in data collection were members of the same dental clinic and pediatric residency program, thereby receiving the same training in clinical examination methods and medical record reporting techniques. As previously noted in chapter 3, all dental residents were trained in plaque scoring and identification of decalcifications during their residency program through seminars and written materials. Furthermore, inter-examiner reliability testing is routinely done every day at the clinic with the attending faculty, to ensure consistency in evaluation of clinical measures.

In addition, evaluation of MS levels was also susceptible to individual interpretation. The agar testing plates were visually inspected for presence of bacterial colony forming units (CFU), which were often difficult to clearly distinguish. The majority of the agar plates were evaluated and MS level assessed by the principal investigator (CLC) who was trained by pediatric dentists (CC and MV) using a standardized protocol developed by the clinic director (Yoon, et al., 2012). On the rare occasion when CLC was not available to personally inspect the agar plates upon their 48-hour incubation due-date, another trained researcher would evaluate the plates and leave the plates in the incubator for secondary analysis by CLC.

Furthermore, analysis of intake occurrence type (i.e., *meal, snack,* or *beverage*) was based on subjective interpretation of intake occurrence. Thus, the limited associations identified with other DECC study measures may be attributable to incorrect labeling of intake occurrence type. Further investigation into the role of intake occurrence type on caries risk is necessary to provide more accurate identification of associations. Since the MSB tool was designed to collect such information directly from participants, during the modified 24-hour recall module, future application of the tool should include systematic collection of this data.

Another potential limitation is that participants completed the MSB risk assessment tool immediately after completion of the comprehensive oral examination. The MSB tool was initially intended to be administered prior to the oral examination; however, in order to minimize burden on clinic operations and to ensure uninterrupted clinic flow, study procedures were conducted after the examination. As per clinic protocol, the dental professional conducting the oral examination collects information on a number of known ECC-related risk factors, many of which are also components of the MSB tool. Therefore, participants were often asked the same questions regarding diet and oral health habits twice. Moreover, the dental health professional provides brief education to parents/caregivers of children undergoing the dental exam. Thus, responses to MSB questions regarding highly cariogenic behaviors may have been bias, as participants may have felt compelled to provide socially desirable responses. If parents provided socially desirable responses, the findings regarding ECC-related behaviors and caries risk may have been impacted. For example, several of the highly cariogenic categories of foods were reportedly consumed by very few participants. It could be that the small sample sizes in some of the high cariogenic food categories were the result of participants responding in a socially desirable way, which may have precluded us from accurately assessing associations with caries risk. Parents of children with previous caries experience may have also been inclined to report socially desirable answers because of previous knowledge of high-risk behaviors; thereby potentially limiting the variability observed among the higher levels of MSB risk scores. In order to mitigate this potential effect, all participants were encouraged to answer MSB questions as honestly as possible, and were reassured that there are no “right” or “wrong” answers. The fact that just over 30 percent of participants reached for the follow-up survey reported making no attempt to achieve their behavior change goals one month post-intervention, lends credence to the possibility that participants answered questions honestly and were not simply reporting socially desirable responses.

Lastly, the DECC study only included children presenting for routine oral examinations and excluded children presenting to the clinic for urgent care or restorative procedures, thus there was a limited range of children with the highest levels of physical indicators of caries risk. Children visiting the clinic for urgent care, surgical, or restorative procedures were not included primarily because it was felt that the majority of parents/caregivers would likely be anxious and concerned about their care, thus making participation difficult. Furthermore, the clinicians may not have collected data on all physical indicators of interest in the DECC study during such visits. Future studies may want to ensure a broader range of physical indicators of caries, to include higher numbers of children presenting within in the highest categories of risk.

5.9 - Generalizability

The findings from the DECC study are limited to the population under investigation. The DECC study participants were primarily Hispanic, mostly foreign born, and low income (70.4% Food Stamp recipients; 62% WIC participants; 99.1% Medicaid recipients). Thus, if MSB were to be used in other populations (e.g. African-American children), the tool would have to be slightly adapted to include appropriate foods/beverages, and would have to be tested for validity in the new population. MSB was tailored to be culturally appropriate for the target population in the DECC study; however, MSB holds the potential for customization to enhance appropriateness for diverse populations. Consequently, future intervention studies may utilize MSB outside of the pediatric dental clinic, and may target other at-risk populations.

Lastly, MSB was designed to address the specific oral health disease of ECC. However, the tool holds the potential to be tailored to address the etiological risk factors associated with nearly any disease or public health concern. For example, MSB may be used as a model for the development of risk assessment and educational tools to address other diseases, of childhood and beyond (e.g., diabetes, obesity, cancer, cardiovascular disease, sexually transmitted diseases, etc.), each of which have specific risk-related behaviors that may be modified through individualized, targeted, intervention approaches similar to those applied in the DECC study.

5.10 – Future Directions

The DECC study raised several interesting questions that could be explored in future studies. First, the findings from the DECC study could inform future versions of the MSB risk assessment tool. Based on findings from the present study, MSB may be revised to assign higher risk weights to specific categories of foods and beverages that were found to be significantly associated in increased caries risk. For example, since intake of the *candy, sweetened yogurt, peanut butter & jelly sandwiches,* and *sauces* categories were significantly associated with worse physical indicators of caries, intake of these categories may warrant higher assignment of risk scores.

Additionally, further investigation into associations with intake occurrence type (i.e., *meals, snacks, beverages*) and caries risk is warranted. Since the designation of intake occurrences as *meals* versus *snacks* via MSB was not consistently documented in the DECC study, future evaluations of the MSB tool should incorporate accurate collection of data on intake occurrence type (*meals* or *snacks*). The MSB tool was designed to collect this information directly from participants, thus future application of the tool should include systematic collection of this information. Future versions of the MSB tool may also consider whether or not the diet assessment module should be weighted more heavily in its contribution to the *Comprehensive* MSB diet score.

The findings from the DECC study also suggest that future application of the MSB tool in a larger population may provide a more clear indication of its ability to predict, and ultimately prevent, future caries. Since investigation of relationships between MSB risk scores and physical indicators of caries were likely inhibited by the limited sample size in the DECC study, future application of MSB with a larger sample of individuals may provide a clearer assessment of its utility as a risk assessment tool. Several of the relationships assessed in the DECC study were not found to be statistically significant; however, findings may be more robust with a larger sample of the population since many were borderline significant. Moreover, since analysis by age quintile revealed an association between MSB *Comprehensive* risk and decalcification in older (but not younger) children, and a potential relationship with ECC status, further investigation into the utility of MSB to identify older children with these stages of disease within a larger sample is warranted.

Another question of interest that was generated from the DECC study findings is in relation to the conceptual model created during the development of MSB. Evaluation of the efficacy of the novel conceptual model for ECC-related behavior used in the development of MSB warrants further investigation. Although the DECC study findings are promising, further exploration into the determinants and constructs of import in the model should be conducted. Future investigations of the MSB tool should also include evaluation of the supplementary questions incorporated in the tool that do not currently contribute to determination of risk scores (e.g., “How difficult is it to cut back on the number of sweets your child eats?” or “Most of the mothers I know brush their children’s teeth daily; how much do you agree with this statement?”). Analysis of these questions in relation to physical indicators of caries may provide insight into other important caries-related factors that should be weighted in the calculation of the *Comprehensive* MSB risk score. Future studies utilizing the MSB tool should investigate the potential utility of these ancillary questions as valid indicators of caries risk.

Since the DECC study did not find significant associations between measures of oral exposure time and physical indicators of caries, questions regarding the ability to evaluate this variable were raised. Future studies should attempt to identify better indicators of this interesting oral exposure variable. In order to more accurately assess oral exposure time, future studies might consider conducting direct observations of meal and snack times, although this would likely be a challenging endeavor.

The DECC study findings also suggest that it would be interesting to investigate longer-term application of the MSB intervention. Although findings from a single follow-up contact with participants were promising, the MSB tool was designed as a customizable assessment and education tool, employed over time, to elicit behavior change. Longer-term use of MSB to the address changing needs and interests of participants may promote enhanced rapport with participants and provide the opportunity to adjust behavioral goals over time. Repeat follow-up with participants would also allow for evaluation of behavior change progress, and reinforcement of behavioral goals. Use of the MSB tool in a longer-term randomized controlled trial would be necessary to evaluate its true potential to influence behavior change and, ultimately, physical indicators of risk.

Lastly, findings from the DECC study raised questions regarding future application of the MSB tool with a more diverse population of participants. Use of the MSB tool in a population of children presenting with a wider range of disease status, could provide a better estimate of the tool's ability to identify children at the highest risk of ECC. The DECC study sample had very few participants in the extreme categories of caries presentation. However, use of the MSB tool in non-dental settings, such as WIC clinics, Head Start programs, schools, or other community-based settings, may provide a more diverse selection of children at varying levels of caries risk.

5.11 – Conclusions

Findings from the DECC study support the utility of novel, individualized approaches to health promotion and disease prevention. Although the findings from the DECC study must be evaluated within the context of the study design and the inherent limitations associated with its design, the findings are encouraging. The associations between dietary intake and physical indicators of caries identified in the DECC study further support the need for ECC-focused dietary guidance. If this impactful oral disease of childhood is to be effectively mitigated, further investigation into innovative risk assessment and intervention approaches must be undertaken.

Behavior modification research has indicated that interventions must be sufficient in duration to promote effective results. Despite the fact that the DECC study did not provide ongoing support to participants to promote behavior change, the follow-up data are promising. With provision of a single intervention session, use of the MSB tool promoted self-reported positive behavior change in a large number of follow-up survey respondents. Therefore, future applications of this tool are warranted to investigate the potential for promoting positive behavior changes to reduce ECC risk and promote disease prevention. Larger, and longer-term studies evaluating the effectiveness of the MSB intervention are needed to investigate its precise impact on behavior change. If rates of ECC and disease-associated outcomes are to be effectively diminished, early identification of children at risk of this highly prevalent oral health condition is essential. MSB appears to be a promising tool for early identification and targeted intervention for ECC reduction and oral health promotion.

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APPENDIX A – Diet Assessment of Caries Risk[1]

Diet assessment of caries risk.

KEY AREA	PROBABLE RESPONSE	RELATIVE RISK	DESIRED BEHAVIOR GUIDELINES*
Number of Meals/Snacks	< 6/day	Low	3-6/day
	> 6/day	Moderate	
Meal/Snack Structure	Structured	Low	Structured meal pattern
	Unstructured/grazing	Moderate	
Sugared Beverages†			
Quantity	< 12 ounces/day	Low	6-8 ounces of 100 percent juice or other sugared beverage/day; < 12 ounces of sugared soda pop/day
	12-20 ounces/day	Moderate	
	> 20 ounces/day	High	
Timing	With meals	Low	With meals
	With snacks	Moderate	
	Between meals/snacks	High	
Frequency	1 exposure/day	Low	1 exposure/day
	2-3 exposures/day	Moderate	
	≥ 4 exposures/day High	High	
Length of exposure	< 15 minutes	Low	< 15 minutes
	15-30 minutes	Moderate	
	> 30 minutes	High	
Drinking style	Straw	Low	Straw
	Open container	Moderate	
	Swishing within mouth	High	

* The desired behavior guidelines are based on dietary guidelines and current practice and are presented for adolescents and adults. Sources: U.S. Department of Agriculture[6] and U.S. Department of Health and Human Services and U.S. Department of Agriculture.[7]

† Sugared beverages include 100 percent juice, juice drinks, soda pop, sports drinks, energy drinks, and sugared coffee and tea.

[1](Marshall, 2009)

APPENDIX B - Caries Management by Risk Assessment (CAMBRA 0-5)[1]

CAMBRA for Dental Providers (0-5) Assessment Tool

Caries Risk Assessment Form for Age 0 to 5

Patient name:__________________________ I.D.#__________ Age__________ Date__________

Initial/base line exam date__________________________ Caries recall date__________________________

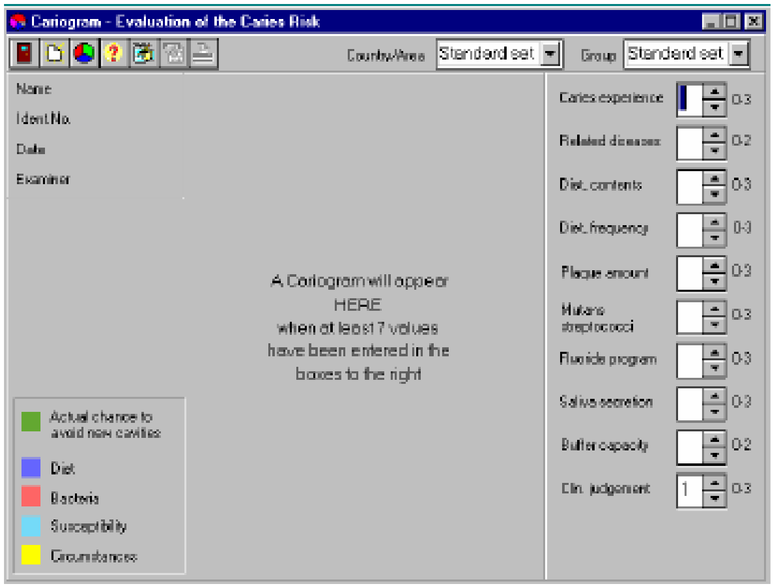
Respond to each question in sections 1, 2, 3, and 4 with a check mark in the "Yes" or "No" column	Yes	No	Notes
1. Caries Risk Indicators — Parent Interview**			
(a) Mother or primary caregiver has had active dental decay in the past 12 months			
(b) Child has recent dental restorations (see 5b below)			
(c) Parent and/or caregiver has low SES (socioeconomic status) and/or low health literacy			
(d) Child has developmental problems			
(e) No dental home/episodic dental care			
2. Caries Risk Factors (Biological) — Parent Interview**			
(a) Child has frequent (greater than three times daily) between-meal snacks of sugars/cooked starch/ sugared beverages			
(b) Child has saliva-reducing factors present, including: 1. Medications (e.g., some for asthma or hyperactivity) 2. Medical (cancer treatment) or genetic factors			
(c) Child continually uses bottle - contains fluids other than water			
(d) Child sleeps with a bottle or nurses on demand			
3. Protective Factors (Nonbiological) — Parent Interview			
(a) Mother/caregiver decay-free last three years			
(b) Child has a dental home and regular dental care			
4. Protective Factors (Biological) — Parent Interview			
(a) Child lives in a fluoridated community or takes fluoride supplements by slowly dissolving or as chewable tablets			
(b) Child's teeth are cleaned with fluoridated toothpaste (pea-size) daily			
(c) Mother/caregiver chews/ sucks xylitol chewing gum/lozenges 2-4x daily			
5. Caries Risk Indicators/Factors — Clinical Examination of Child**			
(a) Obvious white spots, decalcifications, or obvious decay present on the child's teeth			
(b) Restorations placed in the last two years in/on child's teeth			
(c) Plaque is obvious on the child's teeth and/or gums bleed easily			
(d) Child has dental or orthodontic appliances present, fixed or removable: e.g., braces, space maintainers, obturators			
(e) Risk Factor: Visually inadequate saliva flow - dry mouth			
****If yes to any one of 1(a), 1(b), 5(a), or 5(b) or any two in categories 1, 2, 5, consider performing bacterial culture on mother or caregiver and child. Use this as a base line to follow results of antibacterial intervention.**	Parent/Caregiver Date:		Child Date:
(a) Mutans streptococci (Indicate bacterial level: high, medium, low)			
(b) Lactobacillus species (Indicate bacterial level: high, medium, low)			
Child's overall caries risk status: (CIRCLE) Extreme Low	Moderate		High
Recommendations given: Yes________ No________ Date given____________	Date follow up:__________		

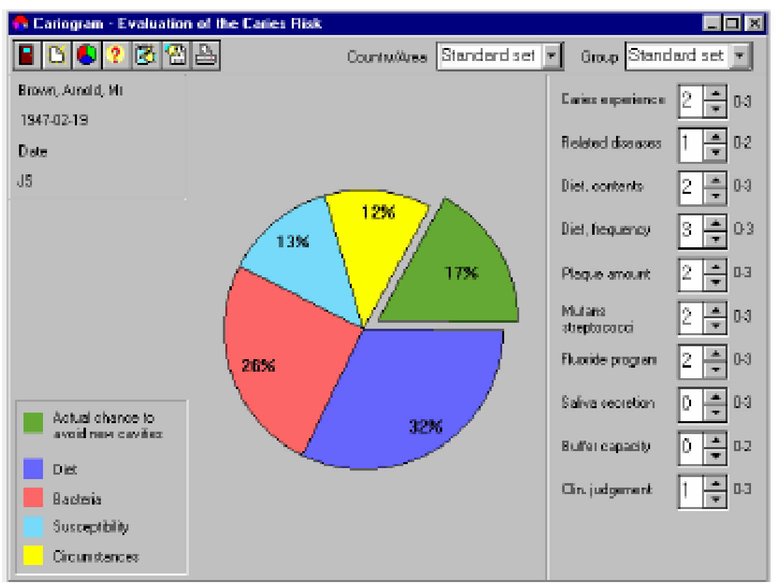
SELF-MANAGEMENT GOALS 1)______________________________ 2)______________________________

Practitioner signature______________________________ Date______________________________

[1](Francisco et al., 2007)

APPENDIX C – Cariogram Risk Assessment[1]





1 (Bratthall & Hansel Petersson, 2005)

APPENDIX D – AAPD Caries –Risk Assessment Tool (CAT)

AAPD Caries-Risk Assessment Tool (CAT)*

Caries-risk Indicators	Low Risk	Moderate Risk	High Risk
Clinical conditions	■ No carious teeth in past 24 mos.	■ Carious teeth in past 24 mos.	■ Carious teeth in past 12 mos.
	■ No enamel demineralization	■ 1 area of enamel demineralization	■ More than 1 area enamel ■ Demineralization (enamel caries "white-spot lesion")
	■ No visible plaque; no gingivitis	■ Gingivitis	■ Visible plaque on anterior (front) teeth
			■ Radiographic enamel caries
			■ High titers of mutans Streptococci
			■ Wearing dental or orthodontic appliances
			■ Enamel hypoplasia
Environmental characteristics	■ Optimal systemic and topical fluoride exposure	■ Suboptimal systemic fluoride exposure with optimal topical exposure	■ Suboptimal topical fluoride exposure
	■ Consumption of simple sugars or foods strongly associated with caries initiation primarily at meal times.	■ Occasional (i.e., 1-2) between-meal exposures to simple sugars or foods strongly associated with caries	■ Frequent (i.e., 3 or more) between meal exposures to simple sugars or foods strongly associated with caries.
	■ High caregiver socioeconomic status	■ Midlevel caregiver socioeconomic status (i.e. eligible for school lunch program or SCHIP)	■ Low-level caregiver socioeconomic status (i.e., eligible for Medicaid)
	■ Regular use of dental care in an established dental home	■ Irregular use of dental services	■ No usual source of dental care
			■ Active caries present in the mother
General health conditions			■ Children with special health care needs
			■ Conditions impairing saliva composition / flow

Risk Category

■ **High Risk:** The presence of a single risk indicator in any area of the "high-risk" category is sufficient to classify a child as being at "high risk".

■ **Moderate Risk:** The presence of at least 1 "moderate risk" indicator and no "high risk" indicators present results in a "moderate risk" classification.

■ **Low Risk:** The child does not have "moderate risk" or "high risk" indicators.

*AAPD, Council on Clinical Affairs, www.aapd.org 2-OH-013 (5/06)

[1](American Academy of Pediatric Dentistry, 2011/2012)

APPENDIX E – MSB Guide and Screenshots

mySmileBuddy **Quickstart Guide**

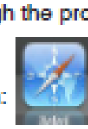
MySmileBuddy is a tool to help you assess a child's risk for severe tooth decay. It is delivered using an iPad. This guide will help you learn how to use MySmileBuddy.

Using the iPad

- To turn the iPad on, click the button on the top edge.
- To wake the iPad up, click the convex button at the bottom of the screen.
- To return to the home screen, as shown at left, click the convex button at the botto of the screen
- More information on how to use the iPad can be found on Apple's site: http://manuals.info.apple.com/en_US/iPad_iOS4_User_Guide.pdf

Starting MySmileBuddy

MySmileBuddy is accessed through the program Safari.

Start Safari by clicking on this icon: 

Type the URL to MySmileBuddy into the URL bar at the top of the screen.

APPENDIX E – MSB Guide and Screenshots (Continued)

log in with your user name and password

This is the main administrative screen for MySmileBuddy. Here you see the list of families that are signed up to do MySmileBuddy. Below this list is the list of health workers working on the project. From this screen you can select a family or families to work with.

When you work with a family you 'check out' that family's account, just like checking out a library book. When you have a family checked out, no one else can enter information for that family. When you are done working with a family, you check them back in and the information you gathered is saved in the database.

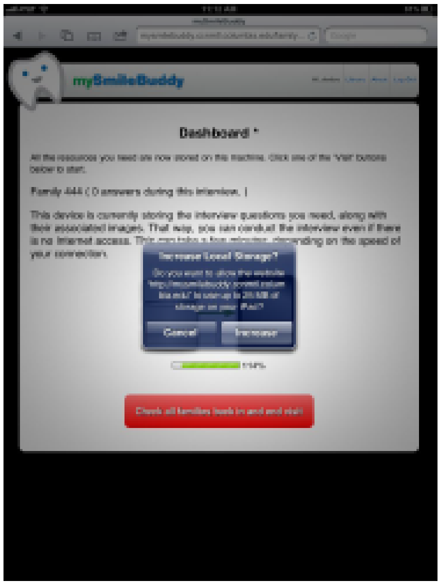
On the left you see two family 444 checked off. When you click 'check out families and start visit' at the top of the screen, this familiy will be checked out to this iPad.

APPENDIX E – MSB Guide and Screenshots (Continued)

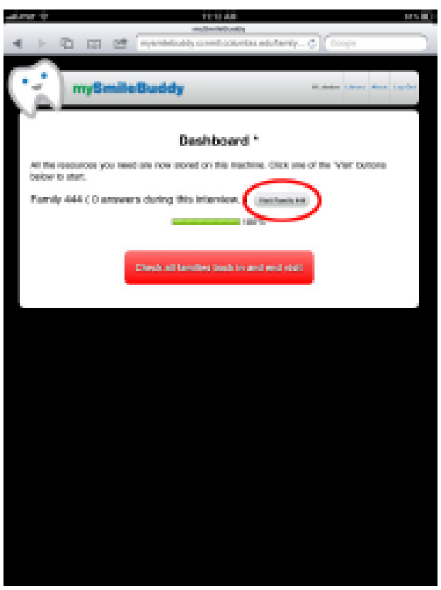
When you check out a family, you download all the materials for them to your iPad. Click 'get materials for visit and start' to start the download.

This is what the screen looks like when the download is in progress.

APPENDIX E – MSB Guide and Screenshots (Continued)



The iPad may ask you if you want to increase local storage to accomodate the files you are downloading. Choose 'Increase.'



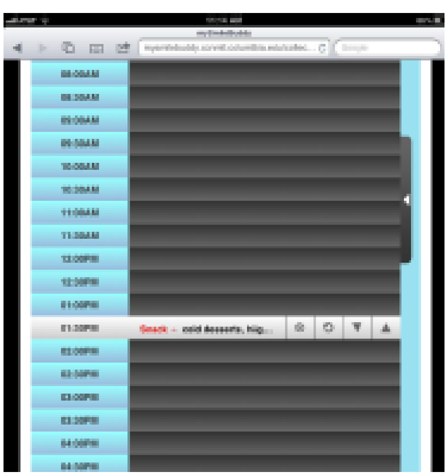
When the download is complete, a button appears next to the family name that says 'visit family ###.' Click this button to begin the assessment.

APPENDIX E – MSB Guide and Screenshots (Continued)

The Food Recall Activity

The third question in the diet module asks 'What did your child eat yesterday?' To answer this question you will do the activity on the screen together with the parent.

- First touch a food to select it. Select as many foods as you need to.
- Next, touch the time line to place the food(s) on the time line
- To see what is already on the time line, touch the arrow between the time line and the food panel



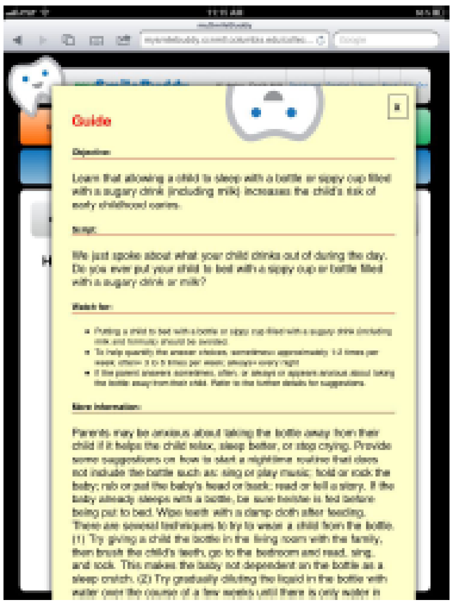
With the time line expanded you can:

- delete a meal event by touching the 'x'
- mark whether an event was a meal or a snack by touching the round arrow
- move the event up or down with the arrows

APPENDIX E – MSB Guide and Screenshots (Continued)

The Help Button

If you need a reminder of what to do on any given screen you can use the help button. The information in the help pop-up on each screen can also help you practice delivering MySmileBuddy.



- touch the 'Help!' button to open the help pop-up
- touch the 'x' in the upper right corner of the pop-up to go back to where you were.

Educational Materials

MySmileBuddy has articles that you can share with parents to help them learn information and skills to improve their child's oral health.

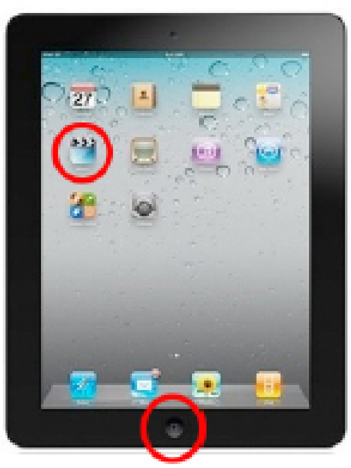
- most questions have a blue 'learn more' button that will open an article related to the content of the question

APPENDIX E – MSB Guide and Screenshots (Continued)

All articals are also located in the library. You can link to the library from the navigation bar at the top of the screen.

Videos

MySmileBuddy has four videos you can share with parents. To access these videos you need to use the video player program on the iPad.

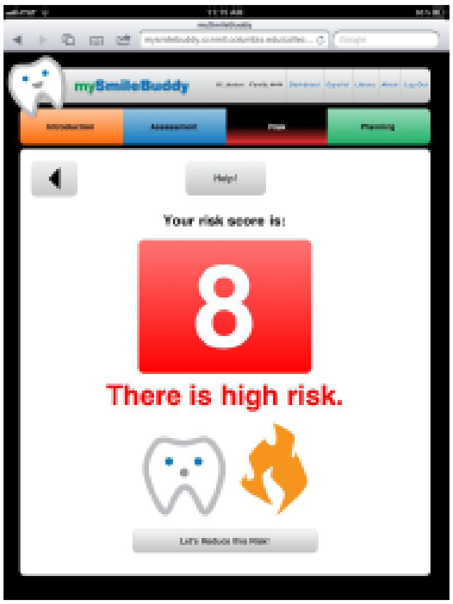


- To leave the assessment without losing your place, just press the home button at the bottom fo the iPad frame.
- Then touch the video player icon to access the videos. 

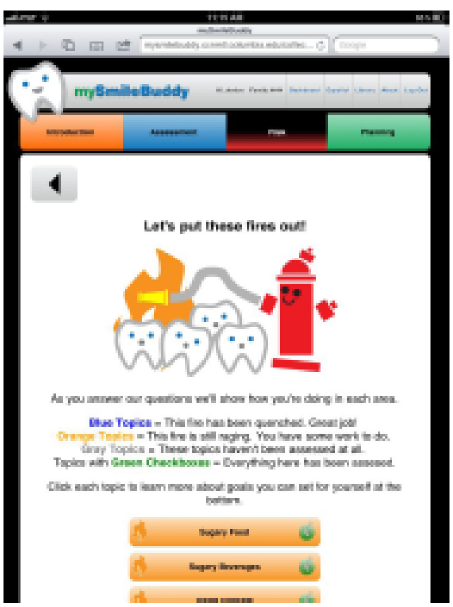
APPENDIX E – MSB Guide and Screenshots (Continued)

The Risk Score

After you are done with the assessment MySmileBuddy calculates a risk score for the family. You do not have to complete every question before you move to the score, but the score will be more accurate if the family completes more of the questions.



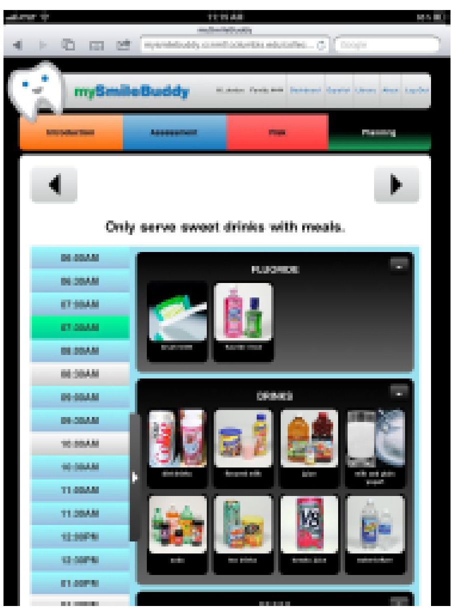
- you get to the risk score by clicking the next button after the last question in the assessment
- or you get to the risk score by clicking on the 'risk' tab in the navigation
- to learn how to lower the risk click the button that says 'let's reduce this risk!'



On the following screen you can show the family which areas they need to work on. Orange topics need work, blue topics are things the family is doing well, gray topics are areas where not all the questions were completed.

APPENDIX E – MSB Guide and Screenshots (Continued)

- Click on a topic to learn about goals the family could set for themselves.
- Then click on 'plan' to go to an area where the family can write about their goal.



If the goal involves changing types of foods or eating times, first the time line comes up so the family can move or change the foods to reflect their goals.

APPENDIX F – MSB Food/Beverage Categories and Cariogenicity

Food	Type	Weight	Sample Foods
Nuts	Caries protective	0	Variety of nuts
Cheese	Non-cariogenic	0	String cheese, packaged slice cheese, cubes of cheese
Eggs	Non-cariogenic	0	Hard -boiled, scrambled, fried, etc.
Meats	Non-cariogenic	0	Chicken, beef, pork, fish
High fiber vegetables	Non-cariogenic	0	Celery, cucumber, broccoli, cauliflower, lettuce, spinach
Unsweetened grain products	Low cariogenic	1	Whole wheat and white bread, buns, tortillas, pasta, rice, plain cereal (cheerios, Wheaties®, Chex®, grits, shredded wheat, oatmeal)
Starchy vegetables	Low cariogenic	1	Plantains, corn, potatoes, yams, peas, carrots, yucca, beans
Fruit	Low cariogenic	1	Berries, mango, apple, grapes, pears, guava
Soup	Low cariogenic	1	Soup
Meat or cheese sandwich	Low cariogenic	1	Turkey sandwich, empanada
Cold desserts	Cariogenic liquid	3	Ice cream, water ice, sherbet, Jell-O®
Sweetened yogurt	Cariogenic liquid	3	Yogurt with fruit on bottom, Gogurt®, Danimals®
Sweeteners	Cariogenic liquid	3	Honey, sugar, syrup
Sauces	Cariogenic liquid	3	Tomato sauce, barbecue sauce, ketchup
Pizza	Solid/retentive cariogenic food	3	Pizza
Macaroni & cheese	Solid/retentive cariogenic food	3	Macaroni & cheese
Spreads	Solid/retentive cariogenic food	4	Jams, jellies, marmalades, peanut butter, Marshmallow Fluff® alone or on bread
Peanut butter & jelly sandwich	Solid/retentive cariogenic food	4	PB&J or jelly sandwich

APPENDIX F – MSB Food/Beverage Categories and Cariogenicity (Continued)

Food	Type	Weight	Sample Foods
Cake like dessert	Solid/retentive cariogenic food	4	Cake, cookies, pie, doughnuts, muffins, sweat breads
Candies	Solid/retentive cariogenic food	4	Twizzlers®, Starburst®, Snickers®, chocolate
Granola bars	Solid/retentive cariogenic food	4	Breakfast bars, granola bars, energy bars
Dried fruits	Solid/retentive cariogenic food	4	Raisin, prunes, dried apricots, banana, canned fruit
Salty Snack foods	Solid/retentive cariogenic food	4	Potato chips, Doritos®, Cheetos®, Tortilla chips, crackers, pretzels, French fries
Sweetened cereals	Solid/retentive cariogenic food	4	Frosted Flakes®, Corn Pops®, Fruit Loops®, Trix®
Hard Candy	Very high cariogenic potential	4	Lollipop, hard candy

Beverage	Type	Weight	Sample Beverages
Plain water or seltzers	Non-cariogenic	0	Tap water, bottled water, flavored seltzer, plain seltzer
Diet and non-sugar drinks	Non- cariogenic	0	Diet Snapple®, Crystal Light®, diet soda
Vegetable juices	Non-cariogenic	0	V8®, tomato juice
Milk	Low cariogenic	1	All plain milk, plain yogurt
Flavored milk	Cariogenic liquids	3	Nesquick® (powdered and premade)
Juice and Juice drinks	Cariogenic liquids	3	100% Juice, Sunny D®, Iced tea, Capri Sun®, juice barrel, etc.
Sugared/ sweetened beverages	Cariogenic liquids	3	Sodas (regular; not including diet)

APPENDIX G – MSB Risk Assessment Modules/Questions

Module	Questions	Responses
Diet	Are you currently receiving WIC?	Yes No
	Is your child a quick eater/drinker or a slow eater/drinker?	Slow eater/drinker Quick eater/drinker
	What did your child eat yesterday?	Modified 24-hour Diet Recall Activity with Timeline and Images of food/Beverage Categories
Feeding Practices	How often do you put your child to bed with a bottle or sippy cup with anything other than water?	Never Sometimes Often Always
	How often does your child sip a sugared drink from a sippy cup or bottle throughout the day?	Always Often Sometimes Never
	How often do you breast feed your child during the night?	Never Sometimes Always Often
	How often do you pre-chew your child's food?	Never Sometimes Always Often
	Where does your child typically eat their meals?	On the go At a table In front of the television
	Where does your child typically eat their snacks?	On the go At a table In front of the television
	How often do you clean your child's pacifier by putting it in your mouth?	Never Sometimes Often Always
	How often do you share utensils or drinks with your child?	Never Sometimes Often Always

APPENDIX G – MSB Risk Assessment Modules/Questions (Continued)

Module	Questions	Responses
Thoughts and Feelings	People in my neighborhood help each other out. How much do you agree with this statement?	I agree I'm not sure I disagree
	Most of the mothers I know brush their children's teeth daily. How much would you say you agree with this statement?	I agree I'm not sure I disagree
	Most of the mothers I know don't let their children have sugary drinks or snacks between meals. How much do you agree with this statement?	I agree I'm not sure I disagree
	How difficult is it to cut back on the number of sweets your child eats?	Difficult I'm not sure Easy
	Products containing fluoride help to strengthen teeth and prevent cavities. How much would you say you agree with this statement?	I agree I disagree I'm not sure
	Cavities can be prevented. How much would you say you agree with this statement?	I agree I'm not sure I disagree
	A mother can pass cavity causing germs to her child. How much do you agree with this statement?	I agree I disagree I'm not sure
	How confident are you in reducing your child's risk for tooth decay?	Confident Not confident I'm not sure
Fluoride	Who usually brushes your child's teeth?	Both me and my child Me My child
	When do your child's teeth get brushed? When does your child rinse with fluoride rinse	Timeline similar to that of the Diet Recall activity, with images of tooth brush and fluoride rinse
	What type of toothpaste does your child most routinely use?	Adult brands with fluoride A variety of pastes Kids' brands with fluoride Kids' brands without fluoride
	Has your child been prescribed prescription toothpaste by a dentist?	Yes No

APPENDIX G – MSB Risk Assessment Modules/Questions (Continued)

Module	Questions	Responses
Fluoride	How many times a week are your child's teeth flossed?	None Once Twice or more
	Other than yourself, is there someone who helps brush your child's teeth?	Yes No
	What is your child's main source of drinking water?	Bottled Tap Both
Family History	Has your child had a routine dental checkup in the last 12 months?	Yes No
	Has your child had a cavity in the last twelve months?	Yes No I'm not sure
	In general, how many problems has your child had with tooth decay?	A lot Some A few None
	Have you (parent or caregiver) ever had an abscessed tooth?	Yes No
	In general, how many problems have you or your other children ever had with tooth decay?	A lot Some A few None

APPENDIX H – MSB Weighting Tool

	abscessed tooth	visit	water	paste	toothbrushing	diet	bottle day	bottle night	pacifier	confidence	Score	Range
Low1	8	1	2	7	1	0	1	1	1	1	25	not
Low2	3	1	2	1	1	1	1	1	1	1	16	not
Low3	3	1	2	1	1	2	1	1	1	1	18	not
Low4	3	1	2	1	1	1	1	1	1	1	16	not
Medium1	3	5	5	3	3	3	6	6	9	5	60	not
Medium2	3	1	5	3	3	1	6	6	9	5	52	not
Medium3	8	5	5	1	3	3	8	8	9	5	69	not
Medium4	3	1	5	3	3	2	8	8	9	5	60	not
High1	3	5	7	1	9	5	9	9	9	9	89	not
High2	8	5	7	7	9	5	9	9	9	9	100	not
High3	8	5	7	7	9	5	9	9	9	9	100	not
High4	8	5	7	7	9	5	9	9	9	9	100	not

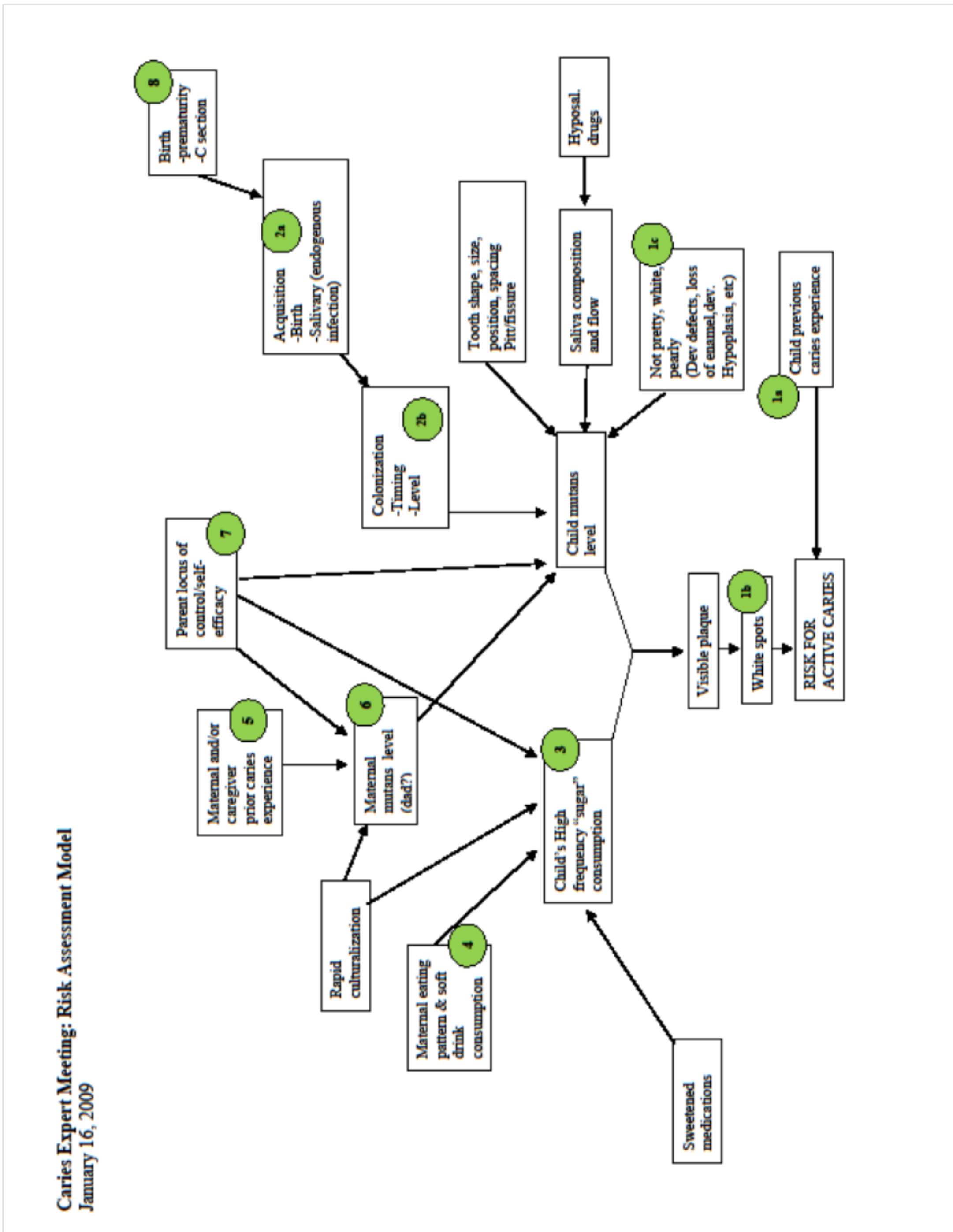
	Cavity	No Cavity
Min	14	0
Max	100	0
Average	53.75	#DIV/0!
Std dev	30.442	#DIV/0!
Mode	16	#N/A
Overlap Range	14	0
# in overlap range	0	0
% in overlap range	0.00%	0.00%

	diet/F x2 , Feec	diet/F x2	Baseline	**Diet x2**	**F x2**
	25	24	23	23	24
	16	15	13	14	14
less 30 low	18	17	14	16	15
30-70 mod	16	15	13	14	14
70+ high	60	54	48	51	51
	52	46	42	43	45
functionally eliminate other variables (0.00	69	61	55	58	58
	60	52	47	49	50
	89	80	66	71	75
	100	91	77	82	86
	100	91	77	82	86
	100	91	77	82	86

Clinical History Module	1
Fluoride Module	2
Diet Module	2
Feeding Practices Module	1.5
Maternal Mutans Module	1
Environmental Module	1
Parent hx question multiplier	1
visit question multiplier	1
water question multiplier	1
paste question multiplier	1
toothbrushing question multiplier	1
diet multiplier	1
bottle day question multiplier	1
bottle night question multiplier	1
pacifier question multiplier	1
confidence question multiplier	1

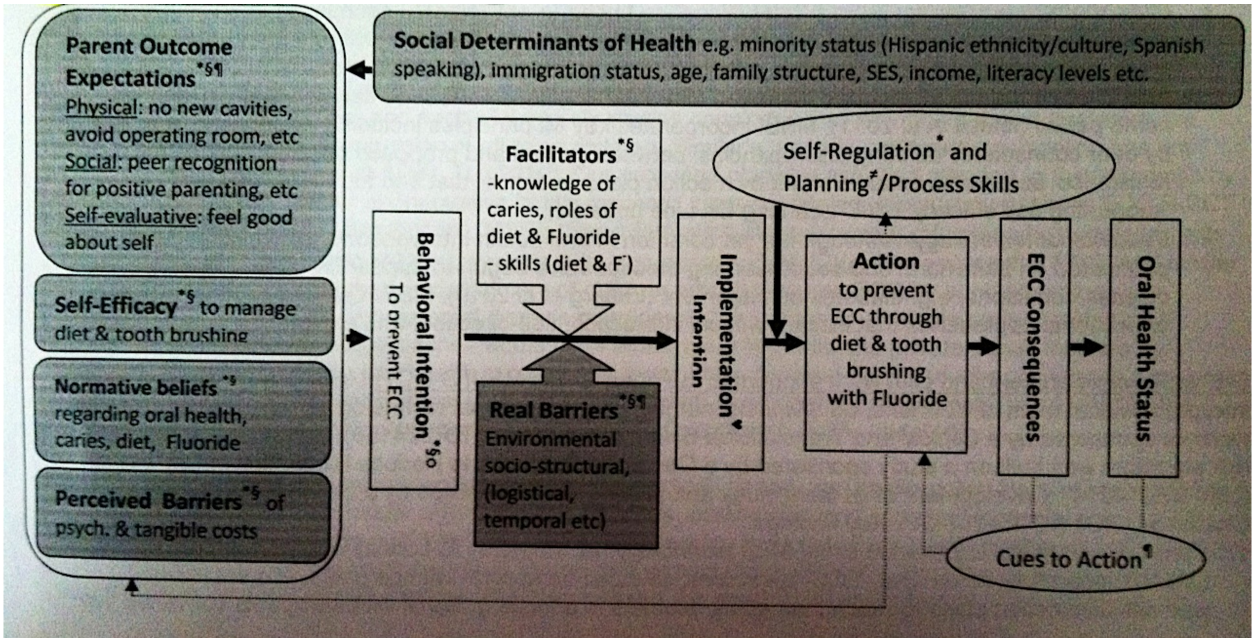
APPENDIX I – Recruitment Flyer

APPENDIX J – MSB Risk Assessment Model[1]



[1](Levine et al., 2012)

APPENDIX K – MSB Conceptual Model for ECC



Conceptual Model Symbol Key:

* Social Cognitive Theory

§ Theory of Planned Behavior

¶ Health Belief Model

♥ Implementation Intentions

This conceptual model is reprinted with the permission of the principal investigator on the MSB development project, Burton Edelstein, DDS, MPH.

APPENDIX L – One-Day Food Record (Back/Front Cover)

Please send my $10 Metrocard to:

Name: ______________________________

Address: ______________________________

____

City: ______________________________

Zip Code: ______________________________

Thank you!

mySmileBuddy

One-day food diary.

Thank you for joining our project on diet and tooth decay. Please record everything your child eats and drinks for one day.

Be sure to note the time they start and stop eating or drinking.

Please return the completed form in the self-addressed, stamped envelope provided the day after you complete the diary. We will then send you a $10 Metrocard as a small thank you for your time.

If you have questions, please call the MySmileBuddy phone number:

(212) 342-0153

Thank you!

Name of the child: ____________________________________

Family #: ____________________________________

*Date to complete: Day:*_______________ */ Date:*____________

APPENDIX L – One-Day Food Record (Inside)

Food Record - SAMPLE.

Meal type	Beginning Time	Food and/or Drinks	Finish time
Breakfast	9.05am	Milk, 1%	9.30am
	"	HoneyNut Cherrios	"
	"	Banana	"
	"	Tropicana orange juice	"
Snack	11.00am	Red apple	11.15am
	"	Goldfish cheddar crackers	"
	"	Sunny D Fruit Punch	"
Lunch	1.30pm	Chicken breast	2.15pm
	"	Mashed potatoes, with butter	"
	"	Hershey's kisses	"
	"	Tropicana orange juice	sipped until 2.45pm
Snack	5.00pm	Yogurt with fruit on the bottom	5.15pm
Dinner	7.45pm	Pepperoni pizza	8.30pm
	"	Tangerine	"
	"	Tropicana orange juice	"
Snack	9.30pm	Milk, 1% and Oreo cookies	9.45pm

Food Record - (TO FILL OUT)

Meal type	Beginning Time	Food and/or Drinks	Finish time

APPENDIX M – One-Month Follow-up Telephone Script

Diet and ECC One Month Follow-up Telephone Script

*Participant Name:*______________________________ *Family #:* __________

Primary Telephone: ______________ *Secondary Telephone:* ______________

Hello, may I please speak with Mr./Ms.____________________?

Note: If the participant is not available to speak, ask when the best time to reach him/her may be.

Suggested Call Back: ______________________________

My name is ____________, I am one of the staff working on the Diet and Early Childhood Caries project at the Columbia University Pediatric Dental Clinic.

I am calling to follow-up with you regarding your participation in the study. As a reminder, when you were at the dental clinic about one month ago, you completed a dental caries risk assessment program on an iPad, called MySmileBuddy.

Do you recall completing MySmileBuddy on the iPad? YES ☐ NO ☐

**Note: If participant does not remember the assessment, provide a brief overview of the features of MySmileBuddy and remind them about the dietary recall component.*

At the end of the MySmileBuddy assessment, you were asked to choose a goal(s) that you wanted to work on to help reduce your child's caries risk.

Do you remember what your goal(s) was? YES ☐ NO ☐

(If "YES") What was the goal(s) you chose to work on?

1. ______________________________

2. ______________________________

**Note: If "NO" remind participant of his/her chosen goal.*

APPENDIX M – One-Month Follow-up Telephone Script (Continued)

What, if anything, have you done to help achieve your goal to ________(state goal)________?

____
____
____
____

Have you made any other changes in your child's diet or oral health habits as a result of the information you learned from MySmileBuddy? YES ☐ NO ☐

(If "YES") What specifically have you changed? ____
____
____
____
____

We thank you very much for your participation in this research project. The information you have provided may help us to better understand how to prevent tooth decay in young children.

Thank you, and have a good day/evening.

APPENDIX N – DECC Participant Caries Experience

Variable[1]	*M* (*SD*)	Range
dft Index (decayed/ filled primary teeth)	2.63 (3.68)	0-15
Tooth Cavity	0.86 (2.12)	0-12
Arrested Tooth Caries	0.1 (0.49)	0-4
Filled Tooth	2.37 (3.37)	0-13
dfs Index (decayed/ filled primary surfaces)	6.26 (11.52)	0-61
Surface Cavity	1.59 (4.36)	0-27
Arrested Surface Caries	0.1 (0.49)	0-4
Filled Surface	4.56 (8.25)	0-45

[1]Data collected from electronic medical record

APPENDIX O - Data Collection Guide

DATA COLLECTION PROCEDURES

DIET & ECC

RECRUITMENT

- Distribute recruitment flyers in examination/ waiting room
- Actively recruit parents/caregivers from examination room and/or waiting room
  - Recruit subset of participants for Food Diary activity; offer opportunity to ALL participants
- Explain all study procedures and ensure participants fully understand details of participation
- For ALL recruited participants, complete Informed Consent and HIPAA Forms
  - Provide participants with a copy for their records
- Distribute complimentary incentives to children
- Note parent/caregiver name and primary/secondary phone numbers on Data Collection Form

PHYSICAL MEASUREMENT

- Collect height and weight measures; record on Data Collection Form
  - *For consistency, weigh all children with shoes and clothing on*
- Once in examination room collect saliva sample for mutans test:
  - Arrange necesary mutans test collection tools:
    - Rubber gloves
    - Mutans testing plate
    - Paper cup
    - Tongue depressor
    - Sharpie Marker
    - Plastic bag (overhead lamp cover)
    - Rubber band
  - Mark mutans testing plate with date and participant code (Initials + MSB Family #)
  - Using rubber gloves, collect small amount of saliva in paper cup or on tongue depressor
  - Transfer saliva to mutans testing plate using tongue depressor
  - Cover mutans testing plate and place in plastic bag
  - Fill bag with air and secure with rubber band
  - Place mutans testing plate in incubator
  - Ensure incubator remains on correct setting
  - Note Incubation End Date and participant code on Data Collection Form

MSB ASSESSMENT

- Play MSB introductory video
- Complete the MSB assessment tool with ALL participants (Use MSB Family # for partipant code)
- Set *one* to *two* goals with all participants
  - Provide appropriate goal setting and educational handouts to participants
- For the Food Diary subset partcipants, explain the Food Diary data collection procedure
  - Provide participants with a copy of the paper-based Food Diary and return envelope
- Thank ALL participants for their time and participation in this study
  - Provide Metrocards in appreciation for participation ($10 for MSB; Second Metrocard to be mailed to subset participants after receipt of completed food diary)

APPENDIX O - Data Collection Guide (continued)

DATA COLLECTION PROCEDURES

DIET & ECC

COLLECT ORAL EXAM DATA

- Collect oral examination data from clinician or electronic Dental Chart
- Record necessary data on Data collection Forms
  - Date
  - Participant Code (Your Initials + MSB Family #)
  - MRN
  - Name (Last, First)
  - Age (Years)
  - Language (Spanish/English/Other)
  - **Visible Plaque (Y/N)**
  - **White Spots/Decalcifications (Y/N)**
  - **Frank Cavittions (#dmft/ #dmfs)**
  - Incubation End Date
  - Mutans Test Results (L/M/H/V)
  - Food Diary (Y/N)
  - One Month Follow-up Date

REVIEW & SUBMIT DATA

- Review Data Collection Form
- Ensure ALL columns are complete
- Submit completed form to Christie at the end of each data collection shift at the clinic

ONE MONTH FOLLOW-UP

- Contact all participants approximately 30 days after recruitment
  - If unable to reach participant, make repeated attempts utilizing both contact numbers
- Complete One-Month Follow-Up Questionnaire
- Submit questionnaires to Christie upon completion

QUESTIONS/ CONCERNS

- If you have any questions/concerns during data collection, feel free to call/text/email Christie *anytime:*
- Cell: (516)991-5817
- Email: clc2123@tc.columbia.edu

APPENDIX P – Data Collection Forms

General Data Form

DATE	PARTICIPANT CODE (CC1000's/DK1100's/AL1200's)	LAST NAME (CHILD)	FIRST NAME (CHILD)	PARENT/CAREGIVER NAME [LAST (If diff), FIRST]	PHONE NUMBER (PRIMARY)	PHONE NUMBER (SECONDARY)	SEX (M/F)	AGE (YRS)	LANGUAGE (S/E/O)	HEIGHT (CM)	WEIGHT (#)	FOOD DIARY (Y/N)	1 MONTH FOLLOW-UP DATE	NOTES / COMMENTS

PHI Data Form

DATE	PARTICIPANT CODE (CC1000's, DK1100's, AL1200's)	PATIENT ID (#)	VISIBLE PLAQUE (MILD/MOD/SEVERE)	WHITE SPOTS/ DECALCIFICATIONS (Y/N)	FRANK CAVITATIONS (#DMFT)	FRANK CAVITATIONS (#DMFS)	INCUBATION END DATE	MUTANS TEST RESULTS (L/M/H/V)	FOOD DIARY (Y/N)	FOOD DIARY RECEIVED (Y/N/NA)	EXAM NOTES

APPENDIX Q – Variable Code Table

Variables	Dependent vs. Independent	Continuous vs. Categorical	Values	Codes
Intake Frequency (Number of Oral Exposures)	Independent	Continuous	0 - ∞ *(Range: 3-12)*	#
Mutans Test Results	Dependent	Categorical (Ordinal)	Low (0 CFU) Moderate (1-50 CFU) High (51-100 CFU) Very High (>100 CFU) (L/M/H/V)	L = 1 M = 2 H = 3 V = 4
Visible Plaque	Dependent	Categorical (Ordinal)	NONE/MILD/MOD/SEVERE	None = 1 Mild = 2 Mod = 3 Severe = 4
White Spots/ Decalcifications	Dependent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
dft	Dependent	Continuous	0 - 20	#
dfs	Dependent	Continuous	0 - 88	#
Food/ Beverage Groups by Cariogenicity	Independent	Categorical (Ordinal)	(0) Caries Protective/ Non- Cariogenic (1) Low Cariogenic (3) Cariogenic Liquid (4) Solid/Retentive Cariogenic food/ Very High Cariogenic Potential	0 1 3 4
MSB Total Score	Independent	Continuous	1-10	1-10
MSB Diet Score	Independent	Categorical (Ordinal)	0 risky occasions = 0 risk score 1-2 risky occasions = 1 risk score 3-4 risky occasions = 6 risk score 5 or more = 9 risk score	0 = Low 1 = Mod 6 = High 9 = Very High
Average Diet Risk	Independent	Continuous	0 - ∞	#

APPENDIX Q – Variable Code Table (continued)

Variables	Dependent vs. Independent	Continuous vs. Categorical	Values	Codes
Average Diet Risk (Including Fluoride Exposures)	Independent	Continuous	0 - ∞	#
Number of Risky Exposures	Independent	Continuous	0 - ∞	#
Average Oral Exposure Time	Independent	Continuous	0 - ∞	#
Total Daily Oral Exposure Time	Independent	Continuous	0 - ∞	#
Quick/Slow Eater/Drinker	Independent	Categorical (Dichotomous)	(Yes) Slow Eater/Drinker (No) Quick Eater/Drinker	Yes = 1 No = 2
% BMI/Age	Independent	Continuous	< 5^{th} Percentile 5^{th} to < 85^{th} Percentile 85^{th} to < 95^{th} Percentile ≥ 95^{th} Percentile	<5^{th} =1 5^{th}- <85^{th} = 2 85^{th}- <95^{th}=3 ≥95^{th} =4
BMI/Age Category	Independent	Categorical (Ordinal)	Underweight Healthy Weight Overweight Obese	Under Wt =1 Health Wt =2 Over Wt =3 Obese =4
Race/ Ethnicity	Independent	Categorical (Nominal)	No Data African American Caucasian Hispanic Asian Native American Other	No Data =1 Afr/Amer =2 Caucasian =3 Hispanic =4 Asian =5 Nat/Amer =6 Other =7
Mother's Educational Level	Independent	Categorical (Ordinal)	No Data Did Not Complete High School Earned a High School Degree More than a High School Degree	No Data =1 Not HS =2 HS =3 >HS =4
Language Preference	Independent	Categorical (Nominal)	(E) English (S) Spanish (E/S) English/Spanish	E =1 S =2 E/S =3

APPENDIX Q – Variable Code Table (continued)

Variables	Dependent vs. Independent	Continuous vs. Categorical	Values	Codes
Mother Born in US	Independent	Categorical (Nominal)	True False	True = 1 False = 2
Sex	Independent	Categorical (Dichotomous)	Male Female	Male = 1 Female = 2
Received Food Stamps	Independent	Categorical (Dichotomous)	True False	True = 1 False = 2
WIC Participation	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Where Eat Meals	Independent	Categorical (Nominal)	On the Go At a Table In Front of Television	Go = 1 Table = 2 TV = 3
Where Eat Snacks	Independent	Categorical (Nominal)	On the Go At a Table In Front of Television	Go = 1 Table = 2 TV = 3
Food/ Beverage Category Consumption	Independent	Categorical (Dichotomous)	25 Food 7 Beverage (32 Total Categories)	As Follows:
Nuts	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Cheese	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Eggs	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Meats	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
High Fiber Vegetables	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Unsweetened Grain Products	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Starchy Vegetables	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Fruit	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Soup	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Meat or Cheese Sandwich	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2

APPENDIX Q – Variable Code Table (continued)

Variables	Dependent vs. Independent	Continuous vs. Categorical	Values	Codes
Cold Desserts	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Sweetened Yogurt	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Sweeteners	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Sauces	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Pizza	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Macaroni and Cheese	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Spreads	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Peanut Butter and Jelly Sandwich	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Cake Like Desserts	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Candies	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Granola Bars	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Dried Fruits	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Salty Snack Foods	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Sweetened Cereals	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Hard Candy	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Plain Water or Seltzers	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Diet and Non-Sugar Drinks	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Vegetable Juices	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Milk	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2

APPENDIX Q – Variable Code Table (continued)

Variables	Dependent vs. Independent	Continuous vs. Categorical	Values	Codes
Flavored Milk	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Juice and Juice Drinks	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Sugared/ Sweetened Beverages	Independent	Categorical (Dichotomous)	Yes No	Yes = 1 No = 2
Food/ Beverage Category Frequency	Independent	Continuous	0-∞ For Each of 25 Food and 7 Beverage Categories (32 Total)	#
Intake Occurrence Type	Independent	Categorical (Nominal)	Meal Snack Beverage	Meal = 1 Snack = 2 Beverage = 3

APPENDIX R – Overview Physical Indicators of Caries Correlation Analyses

Predictor Variables	Oral Mutans	Visible Plaque	Decalcification	ECC Status
Intake Frequency				
Non-Cariogenic Food Group	0.094			
Low Cariogenic Food Group				
Cariogenic Liquid Food Group				0.051
High Cariogenic Food Group				
Non-Cariogenic Beverage Group				
Low Cariogenic Beverage Group				
Cariogenic Beverage Group				
Proportion Non-Cariogenic Beverage Group	0.066			
Proportion Non-Cariogenic Food Group				
MSB Diet Risk Score	0.031	0.061		
Comprehensive MSB Risk Score	0.035	0.043	0.036	
Quick/Slow Eater/Drinker Response				
Average Oral Exposure Time				
Total Oral Exposure Time				
BMI Weight Status				

Note. Participant age and sex was held constant in these OLR analyses; Comprehensive MSB risk score significantly associated with decalcification only via analyses by age quintile.

APPENDIX S – Comparison of Lost-to-Follow-Up and One-Month Survey Completers

	Lost-to-Follow-Up (n = 29)		Completers (n = 79)				
Demographic Variable	*n*	(%)	*n*	(%)	χ^2	*df*	*p*
Child's Race/Ethnicity					1.83	2	0.401
African American	5	(17.2%)	7	(8.9)			
Caucasian	0	(0%)	1	(1.3)			
Hispanic	24	(82.8%)	71	(89.9)			
Parent/Caregiver Immigration Status					0.248	1	0.411
US Born	6	(20.7)	20	(25.3)			
Foreign Born	23	(79.3%)	59	(74.7)			
Parent/Caregiver Language Preference					0.268	2	0.874
Spanish	20	(68.9%)	58	(73.4)			
English	8	(27.6%)	18	(22.8)			
English/Spanish	1	(3.5%)	3	(3.8)			
Parent/Caregiver Educational Achievement					1.326	3	0.723
No Data	1	(3.5%)	7	(8.9)			
Did Not Complete High School	9	(31%)	25	(31.6)			
Completed High School	9	(31%)	26	(32.9)			
Completed More Than High School	10	(34.5%)	21	(26.6)			
Food Stamp Recipient	19	(65.5%)	58	(73.4)	1.31	1	0.252
WIC Participant	19	(65.5%)	48	(60.8)	0.204	1	0.652